



INDIAN AGRICULTURAL
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MGIPC 84-51 AR:57-3-4-58-5,000.

**UNION OF
SOUTH AFRICA**



**DEPARTMENT
OF AGRICULTURE**

**THE
ONDERSTEEPOORT
JOURNAL
OF VETERINARY SCIENCE
AND ANIMAL INDUSTRY**

Edited by P. J. DU TOIT, Director

**VOL. 15, Nos. 1 AND 2
JULY AND OCTOBER, 1940**

**PUBLISHED
QUARTERLY**

**Printed in the Union of South Africa
by the Government Printer
Pretoria
1940**

**DEPARTMENT OF AGRICULTURE AND FORESTRY,
DIRECTOR OF VETERINARY SERVICES,
ONDERSTEEPOORT LABORATORIES,
PRETORIA, SOUTH AFRICA,
OCTOBER, 1940.**

**List of Reports and Journals issued by the
Director of the Onderstepoort Laboratories.**

- Reports of the Government Veterinary Bacteriologist of the Transvaal for the years 1903-10.*
 First Report of the Director of Veterinary Research, August, 1911.*
 Second Report of the Director of Veterinary Research, October, 1912.*
 Third and Fourth Reports of the Director of Veterinary Research, November, 1915.*
 Fifth and Sixth Reports of the Director of Veterinary Research, April, 1918.*
 Seventh and Eighth Reports of the Director of Veterinary Research, April, 1918.*
 Ninth and Tenth Reports of the Director of Veterinary Education and Research, April, 1923.
 Eleventh and Twelfth Reports of the Director of Veterinary Education and Research, Part I, September, 1926.
 Eleventh and Twelfth Reports of the Director of Veterinary Education and Research, Part II, January, 1927.
 Thirteenth and Fourteenth Reports of the Director of Veterinary Education and Research, Parts I and II, October, 1928.
 Fifteenth Report of the Director of Veterinary Services, Parts I and II, October, 1929.
 Sixteenth Report of the Director of Veterinary Services and Animal Industry, August, 1930.
 Seventeenth Report of the Director of Veterinary Services and Animal Industry, Parts I and II, August, 1931.
 Eighteenth Report of the Director of Veterinary Services and Animal Industry, Parts I and II, August, 1932.
 Onderstepoort Journal of Veterinary Science and Animal Industry, Vol. I, No. 1, July, 1933.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. I, No. 2, October, 1933.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. II, No. 1, January, 1934.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. II, No. 2, April, 1934.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. III, No. 1, July, 1934.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. III, No. 2, October, 1934.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. IV, No. 1, January, 1935.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. IV, No. 2, April, 1935.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. V, No. 1, July, 1935.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. V, No. 2, October, 1935.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. VI, No. 1, January, 1936.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. VI, No. 2, April, 1936.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. VII, No. 1, July, 1936.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. VII, No. 2, October, 1936.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. VIII, Nos. 1 and 2, January and April, 1937.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. IX, No. 1, July, 1937.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. IX, No. 2, October, 1937.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. X, No. 1, January, 1938.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. X, No. 2, April, 1938.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. XI, No. 1, July, 1938.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. XI, No. 2, October, 1938.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. XII, No. 1, January, 1939.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. XII, No. 2, April, 1939.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. XIII, Nos. 1 and 2, July and October, 1939.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. XIV, Nos. 1 and 2, January and April, 1940.
 Onderstepoort Journal of Vet. Science and Animal Industry, Vol. XV, Nos. 1 and 2, July and October, 1940.

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Now out of print.

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The Study and Control of the Vectors of Rabies in South Africa.*

By P. S. SNYMAN, Senior Veterinary Officer, Bloemfontein,
Orange Free State.

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PART I.

INTRODUCTION.

IN most countries the epizootology of rabies is usually associated with the rabid dog only, and control measures are aimed at restricting the chance of spread of the disease by biting. Legislation, which is in all countries nearly alike, provides for the destruction of infected animals and for placing under strict veterinary observation of all those suspected of being infected. In order to have efficient control and to prevent the spread of the disease, large areas are proclaimed, and in these "rabies orders" are enforced. These orders aim at restricting the movement of dogs, eliminating stray dogs by licensing, and preventing dogs by muzzling from transmitting the disease. In some instances, furthermore, compulsory immunization of dogs is resorted to.

There are countries, where animals other than dogs play the main rôle in transmitting the disease and where the control problem assumes a totally different aspect. In parts of South America certain species of vampire bats *Phyllostoma superciliatum*, and *Desmodus rufus* in Trinidad, are the chief vectors of the disease, which occurs mainly in cattle. Outbreaks in these countries are remarkable for the disproportion between the small number of rabid dogs and the very large number of diseased cattle. In Trinidad alone during the years 1929, 1930, and 1931, the death rate averaged a thousand animals each year, and 90 per cent. of the animals affected were bovines. Only two cases were observed in dogs. It is obvious, that under these conditions checking the disease is very difficult, since bats cannot easily be destroyed in large numbers. Preventive measures have, therefore, to be resorted to. Metivier (1935) in discussing these measures mentions the construction of batproof cowsheds and stables, repelling the bats by bright illumination, and concludes that vaccination of animals is the most suitable method of control of the disease in Trinidad. Although the conditions and the vectors in South Africa are totally different, the problem nevertheless presents points of similarity with that in South America. In this country, the results of observations for the past ten years show that dogs play a negligible rôle in the dissemination of rabies, and that certain small wild carnivora are the vectors.

Snyman and Thomas (1939) in an exposition of the difficulties attending the control or destruction of these "wild carriers" pointed out that restraint of any kind on wild animals was out of the question, and that total eradication of any one or all of the species concerned in the dissemination of rabies could not be contemplated. Even if undertaken by the State, the cost of such a scheme would be prohibitive and it is doubtful whether anything more than a temporary reduction in numbers would result. It was suggested that extermination on a much reduced scale to include only centres of active infection and the immediately adjoining ground, might have the desired effect. It is clear from the mode of transmission they indicate, that if all infected animals as well as all susceptible ones, which might have come in contact with them are destroyed, the disease must

die out at that point as the virus cannot exist outside living animals. Should the area immediately become reoccupied by uninfected animals this would be of no consequence. The hope was expressed that by treating each successive outbreak of rabies in this fashion, that the incidence of rabies would gradually be reduced.

The peculiarities and difficulties of the problem, as regards the methods of control tried and finally adopted, as well as the experimentation which led up to them, form the subject of this paper.

HISTORICAL.

WRITINGS OF EARLY TRAVELLERS.

Reports on the existence of rabies in South Africa prior to the first authentic outbreak at Port Elizabeth in 1893 are scanty and rather contradictory. While Thunberg (1780) and Amicus (1825) referred to outbreaks of rabies, Barrow (1801) and Livingstone (1857) remarked on the absence of the disease in the country. An isolated outbreak of rabies was reported by Shepstone (1828) in Natal. In 1861 a case was reported at the Wittebergen in the Bethlehem district in "The Friend of the Freestate", a newspaper which circulated in the sixties.

The first authentic record of an outbreak of rabies in South Africa was written by Hutcheon in 1894. The outbreak, which was traced to an imported Airedale terrier, occurred at Port Elizabeth in 1893. The diagnosis was confirmed by subinoculation into rabbits and other animals. The disease spread to Uitenhage, Jansenville, Willowmore and Albany. A very significant statement was made by the Colonial Veterinary Surgeon, Dr. Hutcheon, that he feared lest the disease should be communicated to wild animals such as jackals, but except for the case of an ox, no cases other than in dogs and cats were observed.

Following the outbreak at Port Elizabeth, the disease next made its appearance in Southern Rhodesia in 1902. The incidence rate fluctuated, fewer cases being reported one year and more the following year. In 1911 a severe outbreak occurred again and in 1913 Sinclair, the Chief Veterinary Surgeon was able to report, that a marked decrease in the prevalence of the disease had occurred. Southern Rhodesia apparently remained free from 1913, and no further case was reported until last year (1938) when a positive one occurred on the Northern Rhodesian border.

As was the case with Hutcheon, Gray, the Principal Veterinary Officer, also feared that, owing to the wide distribution of the disease, it would spread to wild carnivora and so lessen the possibility of eradicating it altogether. A few cases were reported in wild carnivora, but in spite of that, it was actually brought under control.

It was only by drastic precautionary measures that the disease did not spread into the Transvaal, when outbreaks occurred near its border. In an area fifty miles wide in the Zoutpansberg district along the Bechuanaland and Southern Rhodesia borders the number of dogs was greatly reduced. Farmers were allowed only two dogs each. These had to be registered, and all stray dogs were destroyed.

The adjoining territories of Bechuanaland Protectorate and South West Africa are not entirely free from rabies. Hobday (1936) reported a case in a native child, and for precautionary measures dog-free belts were formed by destroying some 2,000 dogs.

In South-West Africa, owing to the vastness of the country and the absence of veterinary control in the native areas along the Angola border, the position has remained obscure for a long time.

In 1926 it was reported, that several natives died at a Mission Hospital in Oramboland, with symptoms of hydrophobia, and a "history" of having been bitten by rabid dogs. From information gathered at an investigation, it would appear that the disease has existed there for the past twenty years.

Since 1926 suspected cases have been reported from Ovamboland and Okavango at various intervals. In 1935 the District Surgeon for that area reported, that a hyena entered a native kraal one night and attacked fowls, smashed pots and calabashes, and eventually attacked a native. He reports further that every year isolated cases of hydrophobia occur in natives, and for that year eighteen cases were reported, four coming under European supervision. He concluded, that on clinical grounds there exists no doubt that rabies is present in the area and that the chief carriers are dogs. Reports of rabies in domestic animals other than dogs, chiefly cattle, have also been made from Kuring Kurn in South West Africa.

In July 1938 the Native Commissioner for Okavango succeeded in obtaining the head of a dog, that had showed signs of rabies. "Material" in preservatives was dispatched to Onderstepoort, and a positive diagnosis of rabies was made. Commenting on the outbreak of rabies in that area the Native Commissioner states, that the natives have no love for or interest in their dogs, and merely keep great numbers of them to give alarm at night. Many of the dogs are seldom fed and never watered at the kraals, with the result that they wander from kraal to kraal and prey upon wild animals, and that they are therefore considered to be the main carriers of rabies.

The Southern portion of the Mandated Territory of South-West Africa settled by Europeans has apparently remained free from the disease, except for an unconfirmed case in the Grootfontein district where a European woman, having been bitten by a wild (grey) cat six weeks before, developed symptoms of hydrophobia and died.

NATIVE BELIEFS AND REMINISCENCES OF LOCAL INHABITANTS.

Fitzsimons (1919) makes the following observation when describing the spotted genet (*Genetta felina*): "The saliva of this animal apparently has some poisonous property, but this has not been satisfactorily demonstrated". Further on he says, "Several cases have been reported of men dying two or three weeks after being bitten by genets. In these instances it is stated, that after being severely bitten on the hand or arm by a genet the wound healed satisfactorily, but subsequently violent and sharp pains radiated up the arm from the site of the bite into the shoulder, followed later by symptoms, which seemed to resemble hydrophobia". This statement not only agrees closely with actual cases that have been observed and described in later years, but it is all the more significant that it was written at a time (1919) when hydrophobia was not thought to exist in South Africa.

Cluver (1927) in a report on the suspected cases of hydrophobia in human beings from 1916 to 1927, systematically investigated reports of madness in animals in the Vryburg and Mafeking districts. He remarks on the surprising general belief in these two districts amongst both natives and Europeans that a fatal madness follows the bite of a mad wild cat. The Genet cat being singled out as normally a shy animal and very seldom seen, but when mad it will approach homesteads and attack people. He further mentions, that tales relating to such cases go back twenty years.

Sergeant Roberts (1937) of the South African Police at Vryburg, a keen observer of wild life, informed me in a personal communication that as a boy about 35 years ago the old natives at Sterkstroom in the North Eastern Cape Province where he lived, always warned him that the bite of the Genet cat was fatal, but took effect only after six weeks, when the wounds had healed.

On his arrival in Vryburg in 1906 he heard of the same belief amongst natives, and during his thirty-one years as police officer, he heard and dealt with a number of deaths resulting from the bite of wild animals behaving very strangely.

Of some interest is a tale related to him of a family living near Maribogo. It was stated, that about 1885 three children were playing outside their house when one of them was attacked by a Tsipa (Genet cat), and that the child died a few weeks later.

STUDY AND CONTROL OF THE VECTORS OF RABIES.

Sergeant Roberts feels convinced that on account of the numerous cases related to him from different sources, wild carnivora have been infected with rabies for very many years.

If the information obtained from these various sources is correct, one may assume that rabies existed in the small wild carnivora before the outbreak of 1893 at Port Elizabeth.

BRIEF REVIEW OF LITERATURE DEALING WITH RABIES IN SOUTH AFRICA.

Cluver (1927) described all the suspected cases that had occurred in the Union since 1916, when the first case was discovered. All these cases were diagnosed clinically.

In all, ten cases were recorded from 1916 to 1927. In four of the cases the biting animal was a yellow mongoose (*Cynictis penicillata*). In four others the biting animal was a dog. In one, either a dog or a yellow mongoose appeared to have been responsible for the disease. In the tenth case the history implicated the spotted genet (*Genetta felina*).

These cases all occurred in the Northern part of the Union, in a triangular area formed by Bloemfontein in the South, Mafeking in the North and Ermelo in the North-East.

Mitchell (1929) commenting on the sporadic cases of suspected hydrophobia, stated that all the cases were investigated by the Public Health Department, but none of these cases was confirmed by laboratory examination, owing to unfortunate delay in submitting material.

The first cases, in which the diagnosis was confirmed, occurred on the 20th and 23rd November 1928. On November 17th, 1928, two boys, who had been bitten 19 days previously in an endeavour to catch what appeared to them to be a tame yellow mongoose on the farm Cyfergat 44, Wolmaransstad district, became ill and showed symptoms of hydrophobia. Brain material was submitted to both the Medical Research Institute, Johannesburg and the Veterinary Research Laboratories at Onderstepoort.

The diagnosis at both institutes was confirmed by demonstrating negri bodies and subinoculation into rabbits. Mitchell concluded his report with the remarks, that the long search resulted in establishing the fact, that the infection of rabies or hydrophobia existed in smouldering and enzootic form amongst, and was being perpetuated and spread by the wild fauna over a considerable area of the Union.

Du Toit (1929) in reviewing the rabies problem in South Africa described further cases of rabies in which the diagnosis was confirmed by laboratory methods. The first case in a yellow mongoose, caught on the farm Cyfergat, where the two boys referred to above were bitten in October 1928, was on the 1st April, 1929, and three others viz. in a dog, an ox, and a European child. The last was bitten by a genet cat.

Neitz and Marais (1932) described in detail the experiments conducted with material taken from the two boys at Cyfergat, and on material sent in from cases further outbreaks that had occurred up to that time. Some twenty-six outbreaks were tabulated by them, giving the distribution of the outbreaks and the known carriers.

In 1933 Neitz and Thomas tabulated the cases of rabies that had occurred during 1932, and drew attention to the spread of the disease.

RABIES IN OTHER COUNTRIES.

In spite of the advances, that have been made in the study of rabies, the disease still exists in the majority of countries throughout the world. Australasia is the only continent that is entirely free from rabies.

Europe.

The disease is very prevalent in the Central and Eastern states of the Continent, while England, Belgium, Holland and the Scandinavian Peninsula are the only lands from which the disease has been eradicated.

Of the other countries France, Germany and Italy have the best control of the disease. In Germany only one case has occurred in a human being since 1930, while in France it was diagnosed in 143 dogs and 33 cats during 1937. The disease is worst in the South Eastern States of the Continent. The cases reported for 1937 vary from 256 in Greece, to 708 in Bulgaria. In Yugoslavia in 1936 a great increase in the disease occurred in the mountainous districts, where wolves played a great part as carriers. Over 27,000 cattle in the Province of Vardar were attacked by wolves, which it is thought numbered approximately 10,000. During the same year the disease was diagnosed in 904 dogs, 34 cats, 14 equines, 144 cattle, 50 sheep, 11 goats and 71 pigs. In the following year it was diagnosed in 1,110 dogs and cats, and in 738 other animals.

United States of America.

It is reported that rabies has increased in recent years in the Southern States and during the period 1929-1934, examination for rabies gave positive results in the brains of 4,256 animals in Alabama, 2,912 in Tennessee, 2,757 in Texas, 2,379 in Georgia, 1,097 in Mississippi and 496 in Florida. 86 Per cent. of the domestic animals concerned in the cases of rabies in human-beings were dogs, 6.3 per cent. cows, 4.8 per cent. cats, the rest being horses, rats, goats, hogs, rabbits, and monkeys.

It is further stated, that rabies is quite prevalent in 19 out of 53 states, and that Illinois has more rabies than any other state, only 9 states being free from the disease.

From Canada it is reported that rabies is rare. In 1933 the disease was diagnosed in 7 dogs, 2 bovines and 3 sheep.

South American States and West Indian Islands.

In some of the South American States notably Brazil, Paraguay, British Guiana and others, and certain of the West Indian Islands, e.g. Trinidad and Tobago, the disease assumes quite a different aspect in that the vectors are species of vampire bats. The disease is known as "Mal de Caderas" in Paraguay, Bolivia and the Argentine, and as "Pests das Caderas" in Brazil. In both the furious and quieter forms of the disease an early symptom is inco-ordination of movements, which led to the disease being confused with trypanosomiasis, and therefore called by the same name.

Here the outbreaks are marked by a disproportion between the small number of rabid dogs and the large number of cattle infected. In Trinidad alone during the years 1929, 1930 and 1931 the death rate averaged a thousand animals each year, and ninety per cent. of the animals affected were bovines. Only two cases were seen in dogs.

In Venezuela rabies in dogs is quite prevalent, but more so in foxes. It also occurs in other wild animals, such as the skunk. In the interior of the country, where the grey fox can be seen staring at one on every acre bordering the forests, they come when rabid into the dwelling-houses. During the day they are more dangerous, as they suddenly come round corners and bite young children. At night inhabitants sling their hammocks high to avoid these animals.

Japan.

Great progress has been made in Japan by the adoption of prophylactic vaccination measures. The incidence declined from 1,041 cases in 1918 to 60 in 1930.

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India.

The disease has been known for many centuries, and its wide-spread nature is, owing to the religious views of the natives not to take life, resulting in numerous so-called pariah dogs prowling about the villages. The numerous anti-rabid clinics set up are indicative of the prevalence of the disease.

Malay States.

Mitchell (1930) sums the position up as follows: "In the East, where artificial methods of sanitation are still very rudimentary, nature provides her own means of disposal of waste material by calling to her aid vultures, crows and pariah dogs, and so long as there is an available food-supply pariah dogs will maintain their numbers. The Burman, on account of his religious views, will not willingly take life in any form, and until the rabid animal becomes a menace to human life, little action is taken."

Under these conditions it is only natural that rabies infection is widely disseminated. A small army of suspects is daily treated, at the Pasteur Institute in Rangoon, with a carbolized virus with very good results.

Ceylon.

The disease is prevalent throughout the island, and in 1934 out of 272 suspected cases in dogs, 132 proved positive and in 1936, 253 cases were positive.

Dutch and French India.

The position is the same here as in the Malay States.

Hong Kong.

The main duty of the Veterinary Police consists of enforcing control measures against rabies.

Palestine.

The disease is enzootic in Palestine, and during 1937, 122 cases were reported positive out of 587 suspected cases, and during the same year 19,930 stray dogs were destroyed.

In Iraq, Persia, etc., the disease is very widely spread as no control measures are adopted at all.

The Pacific Islands are considered to be free from the disease.

African Territories.

Rabies is wide-spread on the African Continent, and is more prevalent in the Northern than in the Equatorial and Southern Territories. In North Africa the disease has been known for centuries, and is enzootic. In Morocco, Algiers, Tunis, and Egypt the disease is widely distributed and more than a hundred cases from each country are reported every year. The disease is chiefly caused by ownerless dogs, which stray in the Arab villages, and in spite of drastic measures it seems to be on the increase.

In Central Africa the disease, although wide-spread, is not very prevalent. In the Congo, Cameroons, Sudan, Nigeria, Ivory and Gold Coast, the disease is enzootic appearing as epizootics which die out, and is known as "Oulou-fato", or mad-dog disease. Dogs are the exclusive carriers of the disease, and, although the paralytic form predominates, the virus is the same as that of classical rabies. It is further reported that human-beings very seldom contract the disease, although they are frequently bitten. In British Sudan and Somaliland, Abyssinia, and Eritrea the disease is very prevalent as the result of little control work.

In Kenya the disease was first diagnosed in 1929, and was found to be similar to classical rabies. The jackal is the only important host apart from the dog. In 1935, the disease was diagnosed in seven dogs, fourteen jackals, and one cow.

In Tanganyika the disease has not been diagnosed with certainty, although several suspected cases have been reported of which one was in a human-being.

In 1916 a suspected case occurred in Nyasaland, and in 1924 it was thought that the disease did not exist in the territory, but in 1926 its existence was definitely established.

In Northern Rhodesia the incidence has increased since 1927, and in 1931 one of the seventeen positive cases, that were reported, originated from a jackal. The infection has further been found in cats and monkeys, but has not been noticed in *Fierverridae*.

In the Bechuanaland Protectorate a case was diagnosed in a native child in 1936, and as a prophylactic measure dog-free belts were established and some 2,000 dogs were destroyed.

Southern Rhodesia has been free from the disease since the epizootic which terminated in 1914 until 1938 when a case occurred again in a dog. The outbreak was successfully checked.

In South West Africa the disease has definitely been established in the Okavango area, where it seems to be enzootic.

Madagascar.

In Madagascar rabies is prevalent throughout the island. The dogs, which run all over the island in famished packs congregating around slaughter-houses, fumigators and meat factories, are the main carriers of the disease. In spite of twenty-five years of control, the disease runs yearly through the island with exceptional severity amongst natives, owing to their lack of hygienic measures.

RABIES IN SOUTH AFRICA.

The incidence of rabies in the Union of South Africa may be discussed under the following headings:—

- (1) The distribution of the disease.
- (2) The occurrence of the disease in definite foci or centres.
- (3) The origin of the disease in fresh outbreaks.
- (4) The spread of the disease.
- (5) The possibility of a seasonal influence on the occurrence of rabies.
- (6) The epizootics of rabies that have occurred during the period November, 1928 to August, 1929.

(1) THE DISTRIBUTION OF RABIES.

The distribution of rabies in the Union may be divided according to the incidence rate, into a Central area where the disease is very prevalent, and adjoining this, a North-Eastern and a Southern area where only a few isolated outbreaks have occurred, the Peninsular area in the extreme South of the sub-continent, and the extreme Western area of Griqualand West.

The Central Area.

This area may briefly be described as the area bounded on the West by the Vryburg, Christiana, Boshof, Jacobsdal, Fauresmith and Philippolis districts, on the South and East by the districts of

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Trompsburg, Edenburg, Bloemfontein, Thaba'Nchu, Senekal, Kroonstad and Klerksdorp, and on the North by the Ventersburg, Lichtenburg and Mafeking districts.

The sand-veld, of the Eastern portions of Boshof and Hoopstad districts in the Orange Free State and the Southern portion of Wolmaransstad district in the Transvaal, may be regarded as the centre or nucleus of the area where the disease is most prevalent. The incidence of the disease in this sand-veld area corresponds very closely with the distribution of *Cynictis penicillata*. A study of the relevant map (No. 1) clearly indicates this point.

The North-Eastern Area.

This area may be described as the one adjoining the Central area on the North-Eastern side by the districts of Heilbron, Potchefstroom, and Krugersdorp, and extending eastwards over the Brakpan, Bethal, Middelburg, Carolina, Standerton, and Frankfort districts.

The Southern Area.

Apart from one centre on four adjoining farms with Swartkops as the nucleus in the Middelburg (Cape) district, the infection occurs as isolated spots over the districts of Cradock, Middelburg, Maraisburg, Hanover, De Aar, Britstown, and Carnarvon.

The Peninsular Area.

This is a small isolated area confined to the Cape Peninsula. Two cases, both in dogs, were discovered within a period of two months. There is unfortunately no history associated with these two outbreaks to indicate the source of the infection. Its origin, therefore, remains obscure, especially in view of the great distance from known existing infection in wild animals. It is thought that *Genetta* may be responsible for these outbreaks as genets abound on the slopes of Table Mountain.

The Extreme Western Area of Griqualand West.

This area has recently become infected. An isolated case occurred on 18th August, 1939, in a Genet on the farm Selfdink in the Hay district.

The districts adjoining, and those in between, the areas described above must be regarded as suspected areas.

The incidence of the disease follows the distribution of *Cynictis penicillata* very closely. This is clearly shown by the fact that the disease has never been found in the lime slopes of the Gaap Mountains, a range running through Taungs, Barkly West and Herbert, west of and immediately adjoining the sand-veld. The sharp decline in both the incidence-rate of the diseases and the population density of *Cynictis* is in marked contrast to the gradual decrease to the eastward of the Central area of both the incidence rate and the population density of *Cynictis*.

(2) THE OCCURRENCE OF THE DISEASE IN CENTRES OR FOCI.

As has been pointed out before, Snymman and Thomas consider that although the disease is widespread over a large part of the country, it is restricted to more or less well defined centres over the greater part of that area.

On a large scale map, on which the boundaries of farms are marked, this becomes very evident. The description of a few of these centres will illustrate this.

(i) *The Dealesville Centre.*

The infected mongooses discovered near Dealesville were all found on the Southern portion of the Commonage. At the two adjoining farms of Doornrandjies and Kromspruit, although both outbreaks occurred in oxen, there is, nevertheless, a history of a rabid mongoose in each of the two cases, and the paddocks in which these were found both adjoin that portion of the Dealesville commonage on which the infected viverrids were found. The infection had been known to exist in that comparatively small area for five years without any further spread having been reported.

(ii) *The Groenplaas and Resida Centres.*

The first in Frankfort, and the second in Senekal district, are two very good examples of isolated centres of smouldering rabies infection. In both instances the nearest known infection was some 35-40 miles distant, and both centres are situated in areas where the yellow mongoose is not very abundant.

In the first mentioned centre a low ridge, on which isolated colonies of *Cynictis* are found, passes over both the farms Groenplaas and Boomplaas. It is probable that the infection may exist on the ridge of hills only, as the valleys on both sides of the ridge consist mainly of cultivated lands, where *Cynictis*, if present, would appear in restricted numbers. In view of the fact that no cases, except the one in an ox, were reported subsequent to the death of a European girl, in spite of the sensation created by her death from Hydrophobia following the bite of a *Cynictis*, it may safely be concluded that the disease may smoulder under such circumstances for a long time without being discovered.

(iii) *The Mara Centre, Bloemfontein District.*

From the history obtained on the first case of rabies in this centre it is obvious that the disease has been smouldering there for a number of years. A very careful survey of the viverrid population was made, when the meercat eradication operations (to be described later) were undertaken. It was found, that the two vleis, which pass over the area and which eventually join, allowed the meercats, which abounded there, to come in close association over the two farms on which the outbreaks occurred. See Sketch Map No. 2.

(iv) *The Trompsburg Focus.*

Map No. 6. The Trompsburg Commonage is divided into three grazing camps, known as the cow, calf, and refuse-camps, which are separated from one another by wire fences only. A spruit, which is dry for the greater part of the year, runs through all three camps. The colonies of the yellow mongoose are mainly along the valley in which the spruit runs, except that portion of it which runs through the calf-camp. This interruption of the continuity of the occupation of the valley by the yellow mongoose is caused by the abattoirs, in the vicinity of which no colonies occur. Between the cow-camp and the calf-camp, is a large low-lying plain in which the yellow mongoose, although it has been seen there, has established no known colonies. The plain and the abattoirs on one side and the village on the other side form a barrier between the cow and calf camps which the yellow mongoose very seldom traverses.

From the places marked on the map, where the diseased mongooses have been found, it is obvious that they have all originated from the cow-camp adjoining the town on the South. It is hardly conceivable that mad mongooses would wander through the town and be found on the other side. One must, therefore, accept the probability that the diseased meercats have not come from either the calf or the refuse-camp. Besides both camps are frequented by herd-boys and infected mongoose would have come to their notice in the North, just as they have in the South. It is therefore, accepted, that the infection is confined to the area immediately to the South of the town.

From the above it is obvious that rabies in the lesser carnivora may smoulder on a comparatively small area, three miles square for five years before spreading to adjoining areas, and periods as long as 19 months have elapsed without another case occurring.

(v) *The Swartkoppies focus, Middelburg (Cape).*

In this instance four adjoining farms were infected, and in view of the isolated number of outbreaks in the Southern area, one may conclude that there was a common source of infection. The disease was diagnosed in three different species of *Vicerrids*.

(vi) *The Centres of Rabies Infection in the Vryburg District.*

In this district four centres of infection exist. The first with Middelbult as centre, consists of five farms, which are adjoining and two farms a short distance away. The disease occurred in the following order, a suspected case in an ox, at England in 1926, Zaaiplaas, 1930; Middelbult, 1932; Crondale, 1933; Caledon, 1934; Maizefield, 1936, and Skietpan in 1938. The order in which the outbreaks occurred shows the slow advancing character of the disease. It is difficult to understand that the disease should spread from England, assuming that this farm forms the origin of the infection, to Zaaiplaas and not to Maizefield. Similarly, that it should skip Skietpan to occur at Caledon and to appear five years later only on Skietpan.

The second centre is that formed with Lorenzo, the oldest known infection. In this case there are four farms adjoining in which the infection has been smouldering from 1926 to 1937, a period of almost eleven years, and in the case of the two adjoining farms, Massouwskop and Kromspruit, for a period of six years.

The third centre, consisting of the two farms, Vryburg Commonage and Boston, may be considered as a separate infection. It is, however, possible that it is connected with Kromspruit.

The fourth centre consists of two adjoining farms forty miles away from the nearest infected area of Vryburg town.

(vii) *Hoopstad District.*

Even in this district, where the disease is widespread, it is possible to group infected farms together, so that definite centres of infection are formed. Two such centres, viz., Tevrede and Hestersrust, exist in that area. In the former case where four farms are adjoining, the infection was discovered on three of the four farms in the same year, and six years later only on the fourth farm, Rechtvaardig.

In the case of the other centre, although the four farms which are infected are not adjoining, the area in which they are situated forms a triangle with sides approximately five miles long.

(viii) *Isolated Centres.*

It has been pointed out in the case of the infection on the Trompsburg Commonage, that the disease may exist in a comparatively small area. Further such cases may be mentioned, where infected meercats at different intervals have been found on the same farm and even in the same locality on the farm.

On the Edenburg Town Commonage (see Map No. 5) infected *Cynictis* were found in April and August, 1933, at the points marked X on the sketch map. In June, 1939, a further infected *Cynictis* was found on the same part of the Commonage at the point marked XI.

At the farm Sunnyside, near Bloemfontein, outbreaks of rabies occurred on the 4th and 21st of May and again in July of the same year. All these outbreaks occurred in an area with a radius of less than half a mile. (See Sketch Map No. 4.)

At the farm Philip, in Hoopstad District, an outbreak of rabies occurred in November, 1937, in an ox and on the 23rd of May the following year a rabid *Cynictis* was found in the same camp, where the ox had been grazing. More such cases can be quoted, e.g., Beestekraal in Hoopstad District, of the discovery of the disease in comparatively small areas of approximately 1,000 morgen in extent. These cases further support the view that the disease occurs in restricted areas.

(3) THE ORIGIN OF THE INFECTION IN FRESH OUTBREAKS.

In nearly every fresh outbreak of the disease the same question is raised: What is the origin of the infection? In the absence of any direct evidence, the only reply that can be given is that the disease has always been there, but has remained undiscovered. This reply is based on the presumption, as has been shown above, that rabies may smoulder in the lesser carnivora in a comparatively small area for periods up to eleven years, without being discovered. Most of these isolated "fresh" outbreaks should probably, therefore, not be considered as newly-started foci, but rather as old-established infections that are being discovered.

There are many outbreaks where a single infected animal was found, and without any attempt at eradication, the disease has presumably disappeared. Areas where such sporadic outbreaks have occurred should, therefore, be regarded as suspect until they can be proved otherwise. There are many instances where the disease has appeared recurrently after periods of up to eight years, e.g., Trompsburg Commonage, the farm England in the Vryburg District, Cyfergat in the Wolmaransstad District where the first case that was definitely diagnosed as rabies came from. The first case was diagnosed in two European boys bitten by a *Cynictis* in 1928, and only eight years later another case was recorded on the same farm in a dog.

One often hears it related when dealing with sporadic outbreaks, that animals behaving very strangely were seen there twenty or more years ago. For instance at Ventersvlei, Bloemfontein District, an obviously rabid wild-cat was said to have been discovered near the homestead in broad daylight some twenty years ago. This story is all the more interesting as the nearest known infection is some 30 miles away.

(4) THE SPREAD OF THE DISEASE.

It has often been said that migratory animals will spread an infectious disease as fast and as far as they themselves can travel. Unfortunately very little is known about the migratory habits, if any, of the principal carriers, *Cynictis* and other species of Viverrids. The possibility, that such animals may be removed over long distances as pets, should not be overlooked. A pet *Suricata*, which developed rabies in Carnarvon in 1930, might easily have been the cause of an outbreak in a different part of the country. Similarly, the two pet *Suricates*, to be described later, that were moved to Natal, where *Suricates* do not occur, might also have been the cause of an outbreak.

Several cases are recorded where domestic animals, fortunately cattle only, have been responsible for fresh outbreaks. In the case of Nieuwebaby, Boshof District, the ox concerned was removed from Middelpunt, a farm on which a suspected case of rabies occurred in a domestic cat.

In the outbreak in a donkey on the farm Waagpunt, Boshof District, the animal was removed from the farm Lemoenplaas some 10 miles away, a week before the onset of symptoms. A similar

movement of an infected ox took place during the outbreak at Kommandodrift, Wolmaransstad District. The outbreak reported at Goedgedacht, Ventersburg District, actually occurred in an ox on an adjoining farm where the oxen had been grazing.

Owing to the long period of incubation in rabies, in some cases a period of six months or more, the possibility of spreading the disease by movement of domestic animals is very real and may explain why the disease may at times take unexpected long jumps. However, apart from the few cases mentioned where animals were removed during the incubation period of the disease, it has been found that the disease spreads relatively slowly to adjoining areas by means of wild carriers.

(5) THE PROBABILITY OF A SEASONAL INFLUENCE ON THE OCCURRENCE OF RABIES.

Thomas and Neitz (1933) at the termination of the great drought of that year, speculated on the influence the copious rains and floods, that followed the drought, would have on the incidence of rabies. It was thought, that as a result of the abnormal floods a large proportion of small wild animals would be drowned and so the incidence of rabies be lessened.

The copious rains started in the middle of November only, and the anticipated decline in the incidence rate occurred in September of that year and, therefore, was not related to the rain.

Schumann and Thompson (1934) in a study on South African Rainfall, Secular Variations and Agricultural Aspects, divided the Union of South Africa into 32 districts, on a basis of the distribution of the average monthly rainfall, as well as on the topography of the country.

In their tables the rainfall is indicated as the percentage of the mean rainfall based on data (in the case of districts No. 28 and No. 32) from 1904 to 1933.

From the boundaries of the rainfall districts defined by Schumann and Thompson it was found that the Central Rabies Area as described very nearly coincides with rainfall district No. 30, and the greater portion of No. 28. The small areas of the other districts that are not included in the Central Rabies Areas show only a few isolated outbreaks. The rainfall for the nearest station was obtained for record purposes. The monthly rainfall for the Central Rabies Area was obtained from the Meteorological Office for the years 1929 to 1938. The data of 22 stations were used in compiling the actual monthly rainfall in Graph 1.

Graph No. 1 shows for the Central Rabies Area :—

- (a) The average monthly rainfall.
- (b) The actual monthly precipitation.
- (c) The monthly number of outbreaks of rabies indicated in Table I.

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TABLE I.

Summary of the Incidence of Rabies. 1929-August 1939.

Year.	Jan.	Feb.	Mar.	April.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1929.....	1	1	—	2	2	—	3	2	1	—	1	—	13
1930.....	1	2	2	—	—	—	—	—	3	2	—	—	10
1931.....	1	—	—	1	1	1	—	—	1	—	—	—	5
1932.....	—	—	—	1	2	4	2	2	2	2	—	3	18
1933.....	—	3	2	3	1	4	5	6	—	1	2	—	27
1934.....	2	—	1	—	—	1	1	—	—	1	—	—	6
1935.....	1	—	—	2	1	—	2	3	3	2	2	4	20
1936.....	2	8	1	2	4	3	2	4	5	—	—	—	31
1937.....	1	—	1	—	1	—	—	2	1	—	3	4	13
1938.....	1	—	2	2	4	2	2	5	7	6	—	4	35
1939.....	3	2	1	—	5	2	4	5	—	—	—	—	18
TOTAL.....	13	15	10	13	21	17	21	29	23	14	9	15	179

The Periods during which the Incidence Rate of Rabies was Comparatively High.

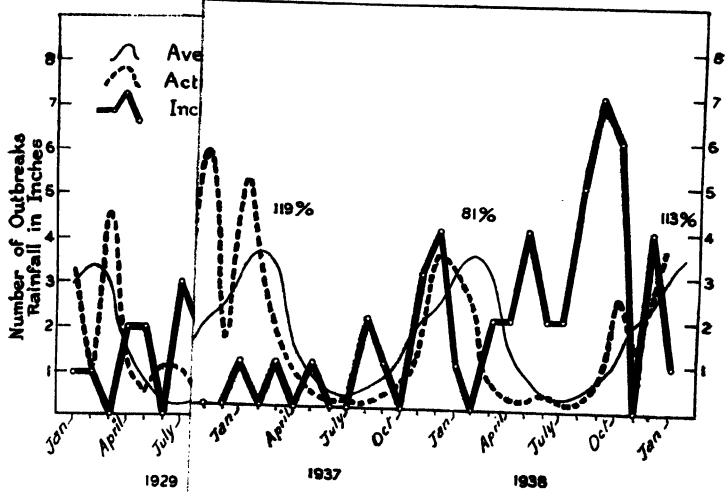
Table II shows the periods in which the incidence rate of rabies was comparatively high.

For the sake of comparing the periods contained in Table II with the seasonal precipitation, the periods have been divided according to the rainfall, into summer for the months November to March; early winter May and June; mid-winter July and August; late winter September and October. The month of April which marks the end of the rainy season and the beginning of winter is given as a separate period.

TABLE II.

The months in which the Incidence Rate of Rabies was Comparatively High.

Summer.	April.	Early Winter.	Mid Winter.	Late Winter.
December, 1932.....	1933	June, 1932....	July, 1929.....	September, 1930.
February, 1933.....		June, 1933....	July, 1933.....	September, 1935.
December, 1935.....		May, 1936....	August, 1933..	September, 1936.
February, 1936.....		May, 1938....	August, 1935..	September, 1938.
November, 1937.....		—	August, 1936..	October, 1938.
December, 1937.....			August, 1938..	
December, 1938.....			August, 1939..	
Total..... 7 times	Once	4 times	7 times	5 times





In comparing the data in Table II with the data in the graph, the following points are rather striking:—

(1) *Early Winter.*

It will be noticed that an increase in the incidence rate of rabies occurred four times during early winter. In three out of the four cases the rainfall for the previous late summer months was far below normal, May, 1936, being the exception.

(2) *Midwinter.*

The incidence rate of rabies increased seven times during midwinter.

(3) *Late Winter.*

The increases in the incidence rate of the disease occurred in each case before any rains had fallen.

(4) *April.*

The only time when an increase occurred during the month of April was in 1933, when an abnormally low rainfall was recorded for the previous summer.

Thus to summarise, the incidence rate of rabies was comparatively high sixteen times when the precipitation was below normal for the previous late summer months or before any rain had fallen. In the 17th case the rainfall for the previous summer was 20 per cent. above normal.

The highest increase in the incidence rate occurred during 1933, late 1936, and 1938, at times when the veld was comparatively bare, especially in 1933 and 1938 when the previous summer rainfall was respectively 32 and 19 per cent. below normal.

(5) *Summer Periods.*

An increase in the incidence rate of rabies occurred seven times during the summer months. On these occasions the climatic conditions were as follows:—

December, 1932.—A little rain fell in the previous September but October and November being dry, the little rain in September had no influence on the veld.

February, 1933.—The increase in the incidence rate of rabies during the summer coincided with one of the worst droughts known in the country.

December, 1935.—The rainfall for the month was above the normal as well as that for the previous two months. So that the increase occurred at a time when the vegetation was well grown.

February, 1936.—The same applies in this case as in the previous one.

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November, 1937.—The preceding two months were dry, when rain should have fallen normally. The veld as can be expected was bare and dry

December, 1937.—The rainfall for the previous two months was far below normal, and that for the same month above normal. But at the time when the incidence rate of the disease reached its peak, the veld was still bare, as the copious rains resulted in dense vegetation only after three weeks.

December, 1938.—Although some rain had fallen in October a very severe frost occurred during the middle of November, and December being still dry the veld was exceedingly bare.

Five out of the seven periods described above may be described as being dry or very dry, resulting in very poor vegetation, and in two of these months severe droughts were recorded.

In the remaining two months, viz. December, 1935, and February, 1936, copious rains had fallen during the preceding month, so that the veld was practically overgrown and the vegetation tall.

It will be seen from the above that the incidence rate of rabies tends to increase during the winter, and that when increases are recorded in summer they coincide with conditions of veld in which the vegetation is very short or almost absent.

On twenty-one occasions out of twenty-four, when a comparatively high incidence rate of rabies was recorded, it coincided with periods when the vegetation was short or no vegetation existed, and on three occasions only occurred when the grass was tall and the veld overgrown.

From the above it may be concluded that drought or scarcity of vegetation to some extent at least influences the number of outbreaks of rabies recorded. This would not necessarily mean that epizootics occur during such periods. The larger number of outbreaks recorded during such periods is probably due to the fact that meercats traverse larger areas searching for food, and when they become rabid they are easily seen, or the scanty vegetation allows such animals to wander further afield than when the grass is high and tall. It is therefore concluded that the increase in the incidence rate of rabies during such periods is only apparent and does not constitute an actual increase in the number of cases that occur normally.

(6) EPIZOOTICS OF RABIES.

Graph 1 indicates that the outbreaks of rabies occur in waves or epizootics. Three such epizootics are evident, viz. one during the period May, 1932, to August, 1933; the second from August, 1935, to September, 1936, and the last one during the period November, 1937, to December, 1938.

The First Epizootic.

The whole of the period, during which this epizootic occurred, coincided with a period of severe drought when vegetation was very scanty. The climax was reached during the last three months of the period when it terminated very suddenly.

The Second Epizootic.

In contrast to the former outbreak there is a gradual rise in the curve until a peak is reached, but although there is a sudden drop from the peak, the curve is still regular until the final peak is reached, when there is again a sudden drop. This epizootic coincided with a comparatively wet period, when the rainfall was from 14 to 20 per cent. more than the average, resulting in abundance of vegetation and food for all three varieties of meercats.

The Third Epizootic.

Although there is some fluctuation in the initial stage, yet there is a gradual rise in the curve which, in contrast to the two former, shows a sharp but well defined termination. The epizootic started after a summer marked with copious rains in the first part of the season, but which ended with a fall below the average and continued through an exceedingly dry summer.

In all three instances the epizootic terminated prior to any rains having fallen, which clearly indicates that the termination in each case cannot be described to drowning of the meercats, or overgrown vegetation obscuring rabid animals.

If all three cases are regarded as definite epizootics then they are very wide spread over the whole of the infected areas of the Union, occurring in each instance over the Western O.F.S., Western Transvaal, and the Eastern portion of Bechuanaland.

Owing to the widely distributed nature of the epizootics occurring over such a large area at the same time it is difficult to conceive that they can be regarded as true epizootics, considering that the disease started from one centre and swept over the country, like the outbreak of rabies that occurred at Port Elizabeth in 1893. The epizootics must rather be regarded in the light of some factor or factors, common to the whole of the area, causing a "flare up" of the disease in the various centres of infection, where the disease was smouldering.

The fact that all three epizootics terminated equally suddenly may be regarded as proof that the common factor or factors ceased to act over the whole of the area affected.

Beyond speculation, it is impossible at this stage, with our meagre knowledge, to state what factor or factors influenced these epizootics. It is only with intensive study of the life-history and migratory habits of the vectors of rabies that knowledge concerning the epizootology of the disease would be gained.

(7) INCIDENCE OF RABIES IN DOMESTIC ANIMALS.

Theiler (1934) stated that biological and histo-pathological investigations proved that the disease encountered in South Africa was identical with the rabies of Europe.

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It is peculiar, therefore, that the dog which plays the most important rôle in the epizootology of the disease in Europe, should only play a secondary rôle in this country. Of the twenty-one cases in dogs, only two can be accounted for by the bites of rabid dogs, and thrice only did it cause rabies in other animals. See Table 4.

Several explanations have been suggested for this, amongst which the following may be regarded as contributory factors.

(i) The dog population in this country is comparatively small especially in the Orange Free State, owing to the heavy tax of ten shillings per head and the severity with which the tax is imposed. During the later half of each financial year, all policemen in the Province have a standing order, by Administrator's Ordinance, to destroy on sight any taxable dogs not carrying the metal disc showing owner's payment for the necessary dog licence. Further the whole of the rabies-infected area falls within the sheep-farming area of the country. Farmers here are loth to keep too many dogs and natives are practically forbidden to keep dogs, owing to the fear of marauding dogs chasing and killing sheep. Sheep-owners are continually on the look out for dogs trespassing on their properties, and any dog straying in the veld is shot and nothing said about it.

In one instance the author was told by a farmer that in six months he had destroyed fourteen dogs trespassing on his property.

In all four of the Provinces of the Union the Ordinances, relating to the keeping of dogs and the dog-tax, authorize the owner or occupier of any land on which stock is kept to destroy any dog found trespassing thereon not under the control or custody of any person.

(ii) The general fear of mad dogs causes the majority of owners to destroy their pets on the slightest suspicion of madness. Such drastic steps are taken easily as the majority of dogs have very little more than sentimental value, and another mongrel is easily obtained to replace the one that has been destroyed.

It is realised, in view of rabies having been spread by dogs to a considerable extent on a previous occasion in South Africa (Port Elizabeth 1893), that the peculiarity of the disease is not entirely due to the above, but that the explanations given must only be regarded as probable contributory factors, and that the peculiarity is similar in nature to that of rabies in the vampire bat of Trinidad and certain South American States, and "Oulou-fato" of French West Africa and the Congo.

(iii) As regards the rôle the other domestic animals play, very little need be said, except that the rabid ox is always a potential source of danger to human-beings. The practice in this country amongst farmers to diagnose any obscure disease as gallsickness and to dose such animals by pulling out the tongue exposes many to the dangers of rabies. In nearly all cases where the animal affected was a bovine, preventive inoculation had to be resorted to, and in one case as many as twenty natives had to be treated. There is one fatal case of a farmer ascribed to this practice.

THE VECTORS OF RABIES IN SOUTH AFRICA.

Du Toit (1936) summarizes the outbreaks of rabies in the Union according to the species of animals in which the disease had been diagnosed.

In 1937 the author, in a discussion on the epizootology of rabies in South Africa, pointed out that taking into account the many outbreaks of rabies in cattle associated with a history of a mad mongoose, and the number of human-being cases in which the vector is definitely known to be *Cynictis*, together with the number of cases of rabies diagnosed in the *Cynictis* itself, it was obvious this species of animal is by far the most important carrier.

Table 3 gives a summary of the incidence of rabies in the various species of animals in which it has been diagnosed by laboratory methods. Some 20 cases in human-beings and 24 in animals have been added in which a laboratory examination was not made, but the history and clinical symptoms were such that rabies could not be excluded. These cases are bracketed in each instance. During 1937 the author dealt with 34 suspected outbreaks of rabies in the Orange Free State. In these 34 outbreaks, material for laboratory examination was not available in ten instances owing to the animals concerned having been shot through the head, or the material being too decomposed to be of any diagnostic value. Of the remaining 24 cases in which a clinical diagnosis of rabies was made, in two instances only was the diagnosis not confirmed. The inclusion of the cases of rabies, which were not confirmed in Table 3 would therefore not materially affect the data.

TABLE 3.

The Incidence of Rabies in the Various Species of Animals.

Species of Animals.	PROVINCE.				
	O.F.S.	Bechuana- land.	Cape.	Trans- vaal.	Total.
Man.....	6 + (11)	1 + (1)	4 + (2)	6 + (6)	17 + (20)
<i>Cynictis penicillata</i>	44 + (6)	4	1 + (3)	11 + (3)	60 + (12)
<i>Suricata suricatta</i>	1	—	2	—	3
<i>Myonax pulverulentus</i>	—	—	1	—	1
<i>Genetta felina</i>	1	6 + (1)	1	—	8 + (1)
<i>Felis</i> spp.....	2	—	1	—	3
<i>Geoscurus capensis</i>	1	2	—	—	3
<i>Ictonyx orangiae</i>	1	—	—	—	1
<i>Cynalopex chama</i>	1	—	—	—	1
Dog.....	12 + (2)	4	2	3	21 + (2)
Cat.....	5 + (2)	5	—	4	14 + (2)
Cattle.....	23 + (6)	6 + (2)	—	18	47 + (8)
Sheep.....	3	—	—	—	3
Pig.....	2	—	—	1 + (1)	3 + (1)
Equine.....	1	1	—	4	6
TOTAL.....	103 + (27)	29 + (4)	12 + (5)	47 + (10)	191 + (46)

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TABLE 4.
The known Vectors implicated.

Species of Animal.	Of Man.	Of Dog.	Of Cat.	Of Cattle.	Of Pig.
<i>Cynictis penicillata</i>	21	3	—	5	—
<i>Genetta felina</i>	3	1	1	—	—
<i>Felis</i> spp.....	2	—	—	—	—
Dog.....	4	2	1	1	1
Cat.....	2	—	—	—	—
Ox.....	1	—	—	—	—
<i>Geosciurus capensis</i>	1	—	—	—	—
DOUBTFUL.....	3	—	—	—	—
TOTAL.....	37	6	2	6	1

(a) WILD ANIMALS.

The wild animals which so far have been proved to carry and transmit rabies are the following in order of their relative importance:—

1. *Cynictis penicillata*.
2. *Genetta felina*.
3. *Felis ocreata* and *Felis negripes*.
4. *Suricata suricatta*.
5. *Geosciurus capensis*.
6. *Myonax pulverulentus*.
7. *Ictonyx orangiae*.
8. *Cynalopea chama*.

In addition to the several species of animals named above, cases of rabies in the jackal and hyena have been reported from the neighbouring territories of Rhodesia and Angola. The other species of carnivora such as the other two species of jackal, the Cape Hunting Dog, the Aardwolf, etc., in fact all of our numerous species of wild carnivora, must be regarded as potential carriers of rabies.

(1) *Cynictis penicillata*. (Illustration 3.)

It has already been shown, that the species most commonly concerned with rabies transmission is *Cynictis penicillata*. This animal has been responsible for the death of some 21 human-beings and five head of cattle, besides causing some 80 known outbreaks of rabies. That the disease is more prevalent in this animal, is not to be ascribed to any greater susceptibility to the virus of rabies, nor does the animal become any more ferocious when rabid than other species of carnivora. The reason is rather to be found in the fact that it is very abundant, living in small colonies near to one another, thus increasing the chances of contact for transmission much more than in the other animals, which are comparatively less abundant, and with a more solitary mode of living.

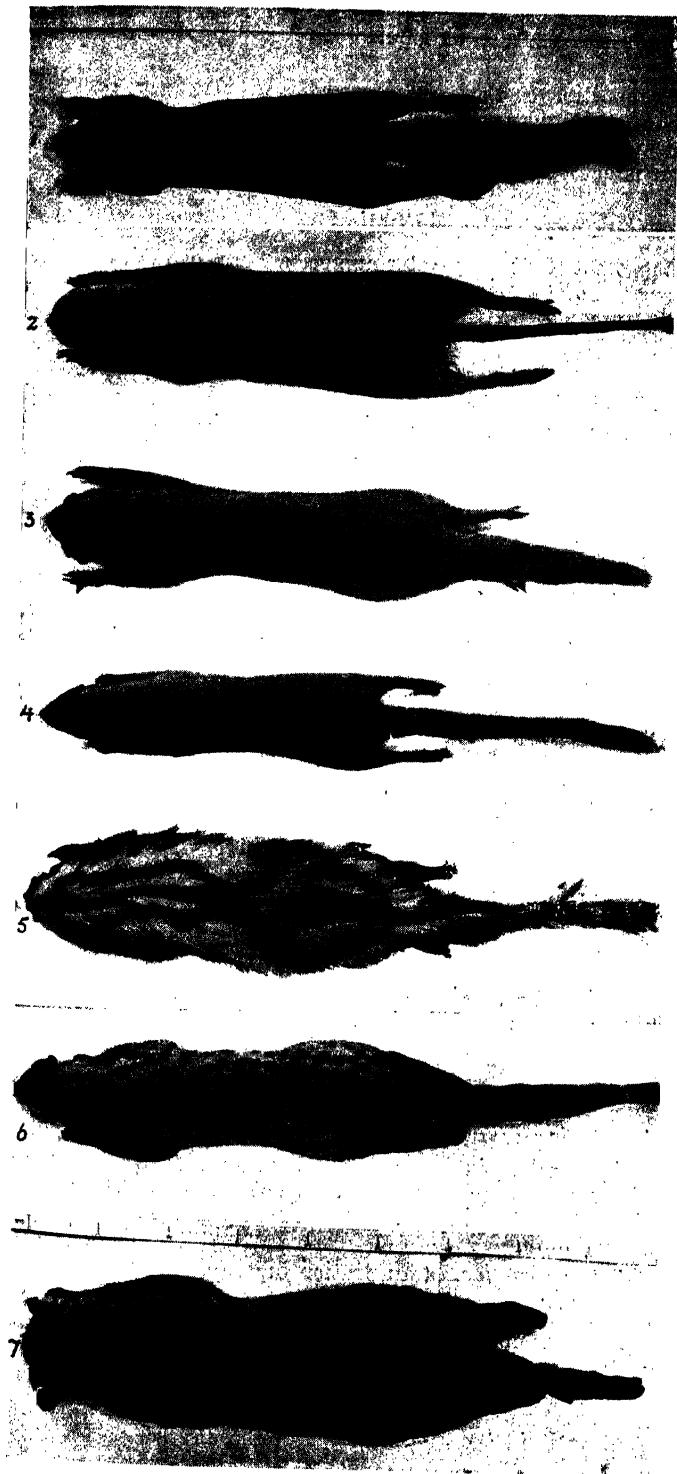


Illustration 1.—*Geosciurus cepensis capensis* (Kerr). Ground squirrel.
 Illustration 2.—*Suricata suricatta hamiltonis* (Thos. and Shuc.). Suricate.
 Illustration 3.—*Cynictis penicillata ogilbyi* (A. Smith). Yellow mongoose.
 Illustration 4.—*Myonax canni canni* (A. Smith). Small grey mongoose.
 Illustration 5.—*Ictonyx striatus striatus* (Perry). Pole cat, skunk.
 Illustration 6.—*Genetta felina felina* (Thunberg). Spotted genet.
 Illustration 7.—*Felis orreata caffra* (Desma and Rest). Wild cat.

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A very large proportion of the cases reported in human-beings are children, who through ignorance and their fondness for pets, are bitten in their endeavours to catch what appears to them to be a tame meercat, but which is actually rabid.

2. *Genetta felina*. (Illustration 6.)

It is interesting to note that the greater number of cases of rabies reported in this species of animal were in the Bechuanaland area, i.e., Vryburg and Mafeking Districts, where this animal also has been suspected for years by the natives as the cause of a fatal disease.

If one takes into consideration that the spotted genet is nocturnal and solitary in its habits then the few cases on record, especially those reported from the Bechuanaland area where it is probably more prevalent than in areas affording less shelter, one may assume that the disease is equally as prevalent in this animal as in the yellow mongoose.

3. *Felis spp.* (Illustration 7.)

Although this animal has a wide distribution over the whole of South Africa, it occurs only in isolated families. The few cases of rabies reported in this animal are therefore commensurable with the smaller chances of contact with this species of animal.

4. *Suricata suricatta*. (Illustration 2.)

The few cases reported in this species probably do not reflect the true state of affairs, if one takes into consideration its wide distribution, gregarious habits, and its close association with *Cynictis penicillata*, often occupying the same burrows. Possibly the fact that these animals are more inclined to wander over large areas in troops may have something to do with this.

5. *Geosciurus capensis*. (Illustration 1.)

While this animal is not a carnivore but a rodent, living in close association with *Cynictis*, cases of rabies in it could be expected. In fact it is surprising more have not been observed. In one case only there is evidence of its having caused the death of a child.

6. *Myonax pulverulentus*. (Illustration 4.)

This animal, being limited in its distribution and occurring in an area where rabies is not very prevalent, does not play a major rôle in the dissemination of the disease.

7. *Ictonyx orangiae*. (Illustration 5.)

Owing to its nocturnal habits, this animal is seldom encountered, but several members of this species have been trapped at the warrens of *Cynictis*. On the farm Riverside in Edenburg district, where the only case of rabies in a polecat has thus far been discovered, meercats are scarce. It is not suspected that the polecat will play a big rôle in the dissemination of the disease.

8. *Cynalopea chama*.

Jackals have long been suspected carriers of rabies. In 1934 a European died of hydrophobia contracted from the bite of a dog, which had fought with a jackal three weeks previously at a native kraal. On the 21st September, 1939, the dogs killed a silver jackal on the farm Rooidam, Jacobsdal district. The brain proved positive for rabies. The skin of a similar animal was identified by Dr. Roberts of the Transvaal Museum as that of *Cynalopea chama*.

In Northern Rhodesia, where the jackal still abounds in great numbers, several cases of rabies have been reported in them; in fact they seem to be the principal vectors there.

In the Union, sheep farmers, in their persistent endeavours to exterminate the destructive Black-backed jackal, have succeeded in reducing the numbers of all three species to a minimum, and over large areas they have been exterminated altogether. In the Karoo, Southern Free State and Griqualand West where the jackal still persists, jackal-proof fencing has been erected at great expense to check raids on small stock.

Although a case of rabies has been discovered in a jackal, it is not suspected that any of the three species play a major rôle in the dissemination of the disease, as not a single case of rabies has been reported in hunting packs, in spite of the large number of jackals hunted by them.

DESCRIPTIONS OF THE VECTORS OF RABIES.

As the epizootology of rabies in South Africa is very closely associated with the habits, mode of life, migration, food, distribution, burrows and colony-formation of the various wild carnivora, a brief description of each of the species of animals concerned with the dissemination of rabies will be given.

The descriptions which follow are based on those given by Selater (1900), Fitzsimons (1919), Roberts (1935), Shortridge (1935), Snyman and Thomas (1939), supplemented by the observations of the officers of the Zoological Survey Section and by personal observations.

The sketch map of the Union of South Africa shows, in the different shades, the estimated population density of *Cynictis penicillata* and its distribution.

The Position of the Viverridae amongst the wild carnivora in South Africa.

All wild carnivora have always been regarded as inimical to man, consequently the larger and the less elusive species have been exterminated in closely settled areas. They are to-day found only in the sparsely populated or uninhabited parts of the country. The smaller and more elusive species have survived in settled areas, even in the vicinity of towns and villages.

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It stands to reason, therefore, that the lion (*Leo leo*), the leopard (*Panthera pardus*), the cheetah (*Acinonyx jubatus*), the hyenas (*Hyaena brunnea* and *Crocuta crocuta*) and the wild dog (*Lycaon pictus*) play no rôle in the rabies problem of this country, but may become of considerable importance, especially the *Lycaon*, which still goes about in large packs and sometimes invades settled areas, should the disease spread to the outlying areas and the game sanctuaries. On the other hand the smaller species composing the *Viverridae* and some of the smaller members of the *Canidae* and *Felidae*, e.g. the jackals and wild cats which have survived in the settled areas and live in close association with man, are greatly concerned with the spread of rabies.

Cynictis penicillata.

English: Yellow mongoose, yellow meercat, red meercat.

Afrikaans: Rooimeerkat, witkwasmeerkat, witpuntstertmeerkat, geelmeerkat.

Xosa: Igola.

Sotho: Mosa, moswe.

Sechuanan: Mushi, musha.

Zulu: N'caciti (Paracynictis?).

The genus *Cynictis* belongs to the sub-family *Herpestinae* of the family *Viverridae*, it contains a number of geographical varieties, of which Roberts lists some twelve.

Distribution.

The distribution of *Cynictis* extends from the Uitenhage and Alexandria districts in the Cape Province, Northwards through Kaffraria where its most Eastern distribution is Kingwilliamstown, thence through the highveld of the Orange Free State and the Transvaal as far as the Drakensberg mountains. From there it extends westward through the Karroo, Namaqualand, Griqualand West, Bechuanaland and Ngamiland into South West Africa, Damaraland (excluding the Namib) up to the Kaokoveld as far as Okovosame, then into western Ovamboland and to the Etosha pan. It does not occur as far North as Grootfontein, S.W.A., and the Caprivi Zipfel. The most thickly populated region is undoubtedly the sandveld of the Western Free State and Transvaal, extending into Vryburg district in Bechuanaland.

Although it has always been regarded as not occurring to the East of the Drakensberg in Natal, I have found a pair in the mist-belt in the Nqutu district about seven miles north of the village. From information obtained from the local natives the *Cynictis*, although very scarce, is known to them and its flesh is relished by piccanins.

In the vast area described above, islands occur in which this species of animal is very scarce or totally absent. One such island appears to be the Eastern slopes of the Gaap mountains up to the Hartz and Vaal rivers, and to some extent on the plateau. I have never seen a yellow mongoose in this area, and this is confirmed by local inhabitants.

Habitat.

The areas selected by *Cynictis* are governed by a combination of various factors such as food supply, occurrence of *Geosciurus capensis*, soft or sandy soil, spruits and water courses, open country devoid of dense bush, etc.

(a) *Food supply.*—As *Cynictis* is primarily insectivorous, one usually finds it plentiful in areas where harvesting termites (*Hodotermes*), which forms its principle food, occur in abundance.

The food supply being the limiting factor of all wild life, one often finds the greatest concentration of these animals near farmyards, especially near cattle kraals and the lairs of cattle, where in addition there is an abundance of dung beetles and their larvae. It is not uncommon to find a few colonies near the gates on grazing commonages and outspans where cattle usually congregate. Very frequently on approaching a gate, one sees a creature disappearing into the stone walls protecting the gate-posts, so familiar in some districts of the Free State. The above statement is substantiated by a glance at the map of Trompsburg Commonage.

(b) *Occurrence of Geosciurus capensis*.—Where other warrens are available the yellow mongoose seldom digs its own. It finds it more convenient to take up quarters in the warrens dug by the ground squirrel, and lives side by side with the latter in the same colony. In places where both species abounds, the ground squirrel determines where they should live. The squirrel, being dependent on bulbs and grass roots for its food, usually elects to dig its warrens near pans, vleis, and water-courses. The *Cynictis*, although preferring higher ground, takes refuge in such places when suitable. The localities of the colonies marked on the map of the Trompsburg Commonage illustrate this point well. On the farm Philip in the Hoopstad district the majority of colonies inhabited by the yellow mongoose was situated along the shallow pan-like depressions, and many mongooses were also found along the slopes of the big pan.

(c) *Soft or Sandy Soil*.—As has been stated before, the *Cynictis* very seldom digs its own warrens, but it will do so in soft or sandy soil. The actual digging and most of the cleaning up of burrows takes place usually after good rains when the soil is moist and easily worked. Where "trassie-bos" mounds, i.e. mounds resulting from wind-blown sand accumulating around *Acacia stolonifera* bushes, occur, nearly every mound is excavated to form a place of refuge. In these mounds the warrens never penetrate below the ground level. On the farm Sunnyside near Bloemfontein, over which the pipe-line for the town water supply passes, the loose soil over the whole length of the pipe-line is riddled with holes, occupied mostly by *Cynictis*. Whether the pioneer was the squirrel, or not, is difficult to say, but there is no reason to doubt that yellow mongooses were responsible for some of them. On the Trompsburg commonage in the "refuse camp", the refuse heaps are honey-combed with warrens.

Sometimes colonies belonging to *Cynictis* are found on the slopes of very stony hills. At first sight one is inclined to think that they have been burrowed in very hard soil, but on excavation it is found that they have been burrowed among and underneath the large rocks, where the soil consists of soft mould. The warrens are usually not very deep, so that reliance for shelter is placed on the overlying heavy rocks.

(d) *Open Country Devoid of Dense Bush*.—Fitzsimons states that, contrary to the statement that these animals are never found in the bush veld, he has frequently observed them in the bush-veld provided that it is not too dense.

In Vryburg district I have met them in the bush, but invariably found their burrows in the more open spaces, yet amongst taller trees like *Acacia giraffae* devoid of dense shrub. In the Hoopstad district they occur on the sand-bults covered with *Acacia giraffae* and other trees.

Except for very dry seasons *Cynictis* avoids flat low-lying plains, and prefers to inhabit colonies on higher ground or ridges. This presumably is done to avoid the water-logging, that is likely to occur in vleis and other low-lying territory.

The *Cynictis*, although primarily an insectivorous animal, has retained its carnivorous habits. Where the harvester termite (*Hodotermes*) is plentiful, it forms an easily accessible and inexhaustible food supply during the greater part of the year. During the autumn days when these termites are particularly active, the yellow mongoose consumes tremendous quantities of them. In several individuals that have been shot on such days, the stomach was found loaded with *Hodotermes* to almost bursting capacity. At other times, or when termites do not occur, every other type of insect, e.g. grasshoppers, spiders, caterpillar and grubs are preyed upon.

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The eggs and the young of ground birds are devoured when found. *Cynictis* is often very troublesome near farmyards where fowls are kept, in that it takes a liking to eggs and chickens, and will show great cunning in regularly plundering the fowls' nests. It is also interesting to see how this animal solves the problem of crushing the egg-shell by repeatedly rolling the egg against a stone until it is broken.

Lizards, toads and frogs are also eaten. The *Cynictis* to a certain extent is also a scavenger. A bird, which had been shot and thrown near a colony was first regarded with suspicion, but was eventually eaten. On one occasion a *Cynictis* was seen eating a springhare carcass, killed by a motorist during the previous night. On another occasion a *Cynictis* was disturbed gnawing at the lips and muzzle of a dead ox.

Food is carried to the young in the mouth. Occasionally fur of rodents (rats and mice) is seen in the dung but contrary to popular belief they rarely form its prey, except when found dead or sick and are thus easily caught.

Fourie (1936) has definitely established that its dung is composed entirely of fur during the height of an epizootic among gerbilles, and that it becomes normal again after the subsidence of mortality. The public Health authorities now recognise that, when rodent fur is found in the excreta of the yellow mongoose, it is an indication of plague or some other epizootic effecting small rodents.

Fitzsimons states, that it at times attacks and devours larger prey, and does not hesitate to follow ground squirrels down their burrows to attack and kill them. This is probably not quite correct. I have seen a squirrel attacking and driving a yellow mongoose away from her warren, into which the mongoose endeavoured to escape when it was fired upon. He further states, that it is not uncommon to find a pair of these meercats in possession of a warren of a "jumping hare" or a ground squirrel, the rightful occupants having been either devoured or driven out. From careful observations it has been found that the yellow mongoose will occupy warrens side by side with these animals without disturbing them.

It has been reported on several occasions, that it attacks newly born and weak lambs, and does not hesitate to devour after-births. As a result of the loss sustained by sheep farmers it has been declared vermin, and three-pence is paid by the Free State Provincial Administration for each *Cynictis* tail presented.

The *Cynictis* is mainly diurnal in habit, but has frequently been observed at night. It hunts either singly or in pairs but not in groups, and it may wander as far as two miles from its abode in search of food.

It usually lives in colonies of two to ten or more animals, but a family usually consists of two to five. The females usually give birth to two young at a time, and probably more than once during the same breeding season, as females in full lactation have been found to be pregnant as well. A pair of well fed young mongooses do not look unlike two well fed puppies.

Suricata suricatta.

English: Cape suricate; common meercat; slender-tailed meercat.

Afrikaans: Stokstertmeerkat; gewone meerkat; graaitjie.

Sesuto: Letoli.

Sechuana: Kotoko.

Five geographical varieties are listed by Roberts. The genus *Suricata*, as in the case of *Cynictis*, belongs to the sub-family *Herpestinae* of the family *Viverridae*.

Distribution.

The suricate has more or less the same distribution as the *Cynictis*. Its distribution in the Cape Province is, however, more restricted.

Being essentially a Karoo animal it does not approach the east coast as close as the *Cynictis*, and does not therefore occur in Kaffraria. Its distribution extends more south and north than that of the *Cynictis*, and as far south as Ceres. It is found on the central high veld of the Transvaal, Orange Free State, Griqualand West, and Bechuanaland. Several large colonies have been seen in the Kalahari region of Kuruman district. In South West Africa its distribution is very limited and occurs only in South Damaraland and Gobabis district. Unlike *Cynictis* the distribution of *Suricata* is very even throughout the area where it occurs.

Habitat.

The suricate, having strong curved front claws, is not like the *Cynictis* dependent on the *Geosciurus* for its warrens. It digs out its burrows in exposed places, preferably on slight elevations to prevent storm water from entering its warrens.

It is, however, unusual to find the suricate occupying the same warrens as the *Cynictis* and the *Geosciurus*. If so, the warrens were probably dug by the latter species.

The suricate is much more migratory in a given locality than either of the other two species of animals, i.e. it wanders within a localized area from colony to colony at short intervals. A large colony was observed near Oliphantshoek, close to a big Camel-thorn tree, along the main road to Kuruman. At times there would be no signs of habitation, and at other times the suricates would be found there again.

The suricate is the most gregarious of the viverrids, and families consisting of ten to thirty or more members are quite common. In one case, on Trompsburg Commonage, a pack of some forty were counted living in one colony.

The migratory habit is probably a necessity to a family of suricates, as they do not wander very far from their warrens in search of food. It stands to reason, therefore, that with a large family traversing only a limited area in close proximity to its warrens, the food supply soon becomes exhausted, whereupon the family has to find a new hunting ground and consequently also a new colony.

Two instances have been described where a migratory pack troop of suricates was followed for some distance. In one a member of the South African Police, on patrol duty on horseback in the Bethulie district, followed a pack of some thirty strong for about two miles along the road. At a turn of the road the suricates carried on, while the police constable turned off. On the farm Elladale in the Umvoti district, Natal, a pair of suricates brought from the Free State as pets, escaped into the veld where they soon multiplied into quite a large family. The farm is situated in the mist-belt, where suricates do not occur. At least two places were known about a mile apart where this family had burrows, which were occupied at different intervals. When one colony was inhabited the other seemed to fall into disuse, but when its turn of occupation arrived fresh excavations were to be found into which the pack would escape on being disturbed. There may have been more such colonies, but only two were located.

Food

The diet of the Suricate is varied. It consumes both vegetable matter such as acorns and rhizomes as well as insects. With its strong claws it can dig out the bulbs it requires, and any insects found are devoured at the same time. On many occasions locusts, grass-hoppers, *hodotermes*, spiders, tarantulas and centipedes have been found amongst the stomach contents of suricates that have been shot.

The breeding period is probably throughout the year and litters of as many as five young have been found in one nest.

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Myonax pulverulentus.

English: Small grey mongoose; Pepper and Salt cat.

Afrikaans: Klein-grys-kommetjiegat; Neuthaar, Garkie.

Xosa: Ilitse.

Sesuto: Mayewane.

The genus *Myonax* belongs to the sub-family *Herpestinae* of the family *Viverridae*.

As a result of its comparative local distribution two varieties only of *Myonax pulverulentus* are described, one of the North West Cape and one of Little Namaqualand.

Distribution.

The *Myonax pulverulentus* is practically restricted to south of the Orange River, where it is widely distributed. Fitzsimmons gives it as common throughout the Cape Province and Natal.

Habitat.

Its favourite haunts are the bush-veld and rocky vegetation hillsides. Nests are found in the crevices of rocks and hollow tree stumps, where the animals live in pairs.

Food.

Its diet consists of rats, mice and insects. It will approach fowl-runs and catch young fowls. It is a pastmaster at killing snakes. Fitzsimmons on one occasion introduced a puff-adder into the cage of a *Myonax*; a battle ensued with the result that the snake was killed, and starting from the head the *Myonax* devoured its victim. It is further described as having a most important mission in the economy of nature, for of all creatures it is the most persistent in its pursuit of rats, mice, and noxious insects and should for this reason not be molested.

Genetta felina.

English: Cape spotted genet; Genet cat (Vryburg).

Afrikaans: Muskejaatkat; Misselkat; Muskkat; Mosaliatkat.

Zulu: Insimba.

Swazi: Insimba.

Xosa: Inyawagi.

Sesuto: Thsipa.

Sechuana: Tsipa.

The genus *Genetta* belongs to the sub-family *Viverrinae* of the family *Viverridae*.

Roberts lists two varieties of *Genetta felina* in South and Tropical Africa.

Distribution.

The *Genetta felina* is the most widely distributed of South African genets, being found from the Cape to the Zambesi and beyond.

Habitat.

Being nocturnal in habits and very secretive, the spotted genet is very rarely seen and encountered. Its habitat is therefore not fully determined. It seems from the number of rabid cases reported from Vryburg, that it is very plentiful in Bechuanaland. It seems to favour well sheltered bushy parts with thick undergrowth. Near Bloemfontein, on the farm Hill-and-Dale it is plentiful. In one year dogs killed no less than five. The farm consists mostly of dolorite koppies overgrown with cactus.

Unless it wanders a great deal it prefers to be near farm-yards to obtain easy prey in the form of chickens.

Food.

The food of the genet consists of any creature it can overpower, hares, rats, mice, birds with their nestlings and eggs, fowls from farm-yards, etc.

Felis spp.

English: Wild cat; Black-footed cat.

Afrikaans: Wildekat; Groukat; Vaalboskat, Swartpootkat.

Zulu: Impaka, Isobila.

Xosa: Ingada, Inxataza.

Sotho: Paka; Mokube.

In the *Felis spp.* are included the two species *Felis ocreata caffra* and *Microfelis negripes negripes*, of the family *Felidae*. Of the first named species Roberts lists four and of the latter two geographical varieties.

Distribution and Habitat.

The distribution of both species of *Felis* is very wide. The *Felis spp.* are found from the Cape to beyond the Zambesi, and frequents hilly country and thick undergrowth where abundant shelter is found during the day.

Food.

Both the species are essentially carnivorous and prey on any animal or bird they can catch. Mice and rats and small birds are very easily caught by these cats. Fowl-houses are frequently visited, from where they will take a fowl and devour it nearby.

Geosciurus capensis.

English: Ground squirrel; Bush-tailed or Fan-tail meercat.

Afrikaans: Waaierstert meerkat.

Sechuana: Samane.

The ground squirrel (*geosciurus*) a rodent, belongs to the family *Sciuridae*. Three varieties have been listed by Roberts.

Distribution.

The distribution of *Geosciurus capensis* is fairly general. It occurs over the whole of the Karoo, Namaqualand up to Ngamiland, including the Kalahari. It is very widely distributed over the high-veld of the Transvaal and Orange Free State, especially in the western parts of these provinces.

Habitat.

The ground squirrel prefers the plains and is very seldom found in hilly country, but may burrow at the foot of isolated hills. Being dependent on bulbs and tubers it congregates near pans and water courses, digging its warrens on the slopes.

Its strong and well-developed front claws are well adapted to dig extensive warrens in fairly hard soil and shale. In the Kalahari it prefers to burrow in lime-outcrops between the sand dunes, as it is probably difficult to keep the burrows open in the loose sand. Where mealie fields exist colonies of the ground squirrel are usually found nearby and even in these fields.

It is generally accepted that this animal does not go far afield for its food but grazes in the vicinity of its burrows. On several occasions squirrels have been caught at their burrows situated more than 800 yards from mealie-fields, with the stomach contents showing that they had fed on mealies.

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The ground squirrel is a sociable animal, living in groups up to eight or more in the same colony. Where unsuitable ground exists for digging warrens as in the isolated lime-outcrops in the Kalahari the offspring remain with their parents, so that the groups increase to twenty or more animals occupying the same colony. The breeding season continues probably right through the summer. The squirrel is very careful about its nests, which consist of chambers dug out of the tunnels and filled with soft grass and other fluffy material which it can obtain.

Food.

The diet of the ground squirrel which is entirely vegetable, consists mainly of "uintjes" and other rhizomes, corms, tubers, gourds, cactus-leaves, grain and grass seeds, etc. Great damage can be done in mealie-fields when these are near the colonies; especially is this the case in newly planted fields where row upon row of the seed is dug up as soon as it has germinated and the green shoots appear above the ground.

Ictonyx orangiae.

The genus *Ictonyx* of the family *Mustelidae* is represented in South Africa by three species, viz., *Ictonyx striatus*, *I. kalaharicus*, and *I. orangiae* with several varieties. Roberts lists five of the first species, three of the second and four of the last named.

The three species are commonly not differentiated and are referred to collectively as "Polecats", or "Skunks".

English: Polecat; Skunk.

Afrikaans: Stinkmuishond.

Sechuana: Nakedi.

Sesutu: Thikgoe.

Zulu: Igaga.

Xosa: Igaga.

Distribution.

The striped polecat is found over the whole of Africa, and is the most ubiquitous of all animals, being equally at home in mountains, waterless sand planes, the Karoo, the bushveld, and swamps. The other two species of polecats have a comparatively limited distribution. *Ictonyx kalaharicus* occurs in the Kalahari region of Bechuanaland and South West Africa. *Ictonyx orangiae* extends over the O.F.S., Namaqualand, Transvaal, Zululand, and Ghansi to Damaraland.

Habits.

The polecats are of solitary and nocturnal habits, occasionally hunting in pairs. A family of these was encountered at night in the midlands of Natal. During the day they hide in crevices and burrows, and although terrestrial, can scramble into trees. The characteristic nauseating odour given off when they are frightened or attacked originates from a fluid secreted in the anal glands. The stink adheres to dogs for days after they have killed a polecat.

Food.

Polecats are more essentially carnivorous than mongooses, they prey very largely on rodents which they often dig out of their warrens. They kill and devour snakes, lizards, the nestlings of terrestrial birds, and are at the same time fearless poultry raiders.

Owing to their persistent destruction of small rodents, they should be protected, as they render valuable service in keeping down the numbers of the gerbilles which are largely concerned with the dissemination of Bubonic plague.

The Jackal.

Although there is a big difference between the three species of jackals found in South Africa, they are very often confused. The three species are *Otocyon megalotus*, *Cynalopex chama* and *Thos mesomelas*. *Chaeffia adusta*, which is unknown in the rabies areas, occurs in the tropical parts of Zululand, Rhodesia, and further north.

Otocyon megalotus.

English: Desert fox; Cape Fennec.

Afrikaans: Draaijakkals; Bakoorkakkals.

Sechuana: Mathlose; Maclusi.

Distribution.

Two geographical varieties are listed by Roberts. The *Otocyon* occurs in dry western parts of South Africa, viz.: on the Karoo plains, Bechuanaland, North-western Transvaal, and South West Africa. In the Kalahari region, where it occurs in great numbers, the natives hunt them for their pelts, for which they obtain two shillings a piece.

Habits.

It is nocturnal in habit, but ventures in daylight into the more secluded parts of the country.

Food.

The animal, although listed as vermin and for whose destruction a reward is paid, is really a harmless animal. Its diet consists mostly of termites, beetles, locusts, small rodents, lizards, and the eggs and nestlings of terrestrial birds. Farmers in the Karoo maintain that it catches new born lambs. Owing to its destruction of Gerbilles, which play such an important rôle in the dissemination of bubonic plague, it should really receive protection.

The sheep farmers unfortunately, in their endeavours to exterminate the destructive Red or Black-backed jackal, have almost completely exterminated this animal, as it is less elusive than the former.

Cynalopex chama.

English: Silver jackal.

Afrikaans: Silwer, Vaal or Draai-jakkals.

Sechuana: Losi.

Sesutu: Mopheme.

Distribution.

The distribution is more or less the same as that of the Cape Fennec, but it is nowhere common. Its range is restricted to South Africa south of the Zambesi, it occurs on the Cape Flats, the Karoo, Orange Free State, Western parts of Transvaal, Bechuanaland, South-West Africa, but not beyond north of Grootfontein, and does not occur in the Caprivi Zipfel. It is also absent east of the Drakensberg.

Habits.

Being of a secretive disposition and nocturnal in habit, it is very seldom seen. During day-time it lies hidden in the thick undergrowth, preferably in thick matted thorny bushes and concentrates round the base of hills and kopjes for shelter. It is less easily caught by dogs than the "bakoork".

Food.

The diet is the same as that of *Otocyon*, but it is claimed by farmers that *Cynalopex* is more destructive to lambs, catching fairly strong ones.

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Thos mesomelas.

English: Common jackal, Black-back, Silver-back or Saddle-back; Red or Cape jackal.

Afrikaans: Rooi- of Swartrugjakkals; Saalrugjakkals.

Sechuana-Sesutu: Phokojoe.

Xosa: Impungutshe.

Zulu: Nkanka.

Distribution.

This is the commonest jackal, and occurs everywhere from the Cape to the Zambesi.

Habits.

This animal, although nocturnal in habit will venture out in day-time as well. It hides in dense scrub and in hilly country, where it can find suitable shelter.

Food.

It is more carnivorous than either of the other two species of jackal. It subsists mainly on rodents and wild birds, besides being a scavenger. In spite of its being a scavenger it is very seldom caught in traps or killed with poisonous bait, as it is exceedingly cunning and has a very fine scent. It is most destructive to the sheep farmer, catching and killing young sheep. On account of this destructive habit it has cost sheep farmers thousands of pounds through loss of sheep and the protective erection of jackal-proof fencing.

PART II.

PREVIOUS ATTEMPTS AT DESTRUCTION OF THE VECTORS OF RABIES.

As early as 1930 (Neitz and Marais, 1932) it was realised that rabies was firmly established in some of our wild animals, and especially in the *Viverridae*. In order, therefore, to reduce the incidence of rabies an extermination campaign of meercats on infected and adjoining farms by gassing with cyanide was undertaken by the Department. From February, 1930, to June, 1931, forty-three farms in the Transvaal, Orange Free State, and the Cape Province were treated.

White (1932) in his report on the above campaign made two statements which dispelled all hopes of success, and as a result of which the campaign was abandoned. In the first place he mentioned that reinfestation by meercats of a treated farm, took place even before the gassing operations on that farm were completed. In the second place failure was ascribed to the fact that the gas, especially after abundant rains, was not always effective.

It is also noted that outbreaks of rabies reoccurred on some of the infected farms on which the extermination of meercats had been undertaken, e.g., Cyfergat, in the Wolmaransstad District on 20.8.36; in the Orange Free State at Dealesville on 16.6.32, and subsequently at Kromspruit on the 4.11.35, and at Brandfort on 18.9.35.

Thornton (1935) described the want of success in destroying veld rodents in connection with plague control, as due to (1) the use of spent dust or defective equipment; (2) the preliminary closing up of the entrances, thus preventing effective penetration of all the underground passages by the dust; (3) the treatment of apparently occupied warrens only, and the neglect of deserted or spare warrens, and (4) the gassing of burrows while the ground is saturated with moisture, or while the animals are out feeding.

STUDY OF THE STRUCTURE OF MEERCAT BURROWS.

In 1936, when it seemed that the incidence of rabies was increasing, and it was realised that all measures of control would fail unless the disease was checked in the wild carriers, experimental work was planned and carried out with a view to discovering the best means of achieving this.

It was obvious, that an accurate knowledge of the internal structure of the colonies and burrows was required, in order to devise the best methods for fumigation, and to determine the causes of failure to kill these animals in the warrens.

A preliminary investigation was started near Wesselsbron, where an outbreak of rabies had occurred. These preliminary investigations, conducted under the direction of Dr. Thomas, consisted chiefly of studying the formation of the colonies and the structure of the burrows of the *Cynictis*, *Geosciurus*, and *Suricata*.

A considerable number of colonies, both small and large were dug up, during the course of these and subsequent experiments, and they were described and sketched to scale.

PROCEDURE FOLLOWED IN THE STUDY OF BURROWS.

The procedure adopted was shortly as follows: Two wires were stretched at right-angles across the colony, and staked. These wires then represented the co-ordinates. Corresponding co-ordinates were drawn on graph paper. The most convenient scale was found to be five feet to the inch.

The positions of the openings of the warrens were measured from the co-ordinates with a tape-measure and were marked as small circles on the sketch. Digging operations were then started at one or more openings, and the warrens were carefully followed. As the digging progressed, the depth and directions of the warrens were measured in the same way from the co-ordinates, and traced on the graph paper as accurately as possible.

DESCRIPTION OF THE BURROWS.

The three above-mentioned species of burrowing animals dig their burrows very much on the same intricate pattern, which is more easily illustrated than described.

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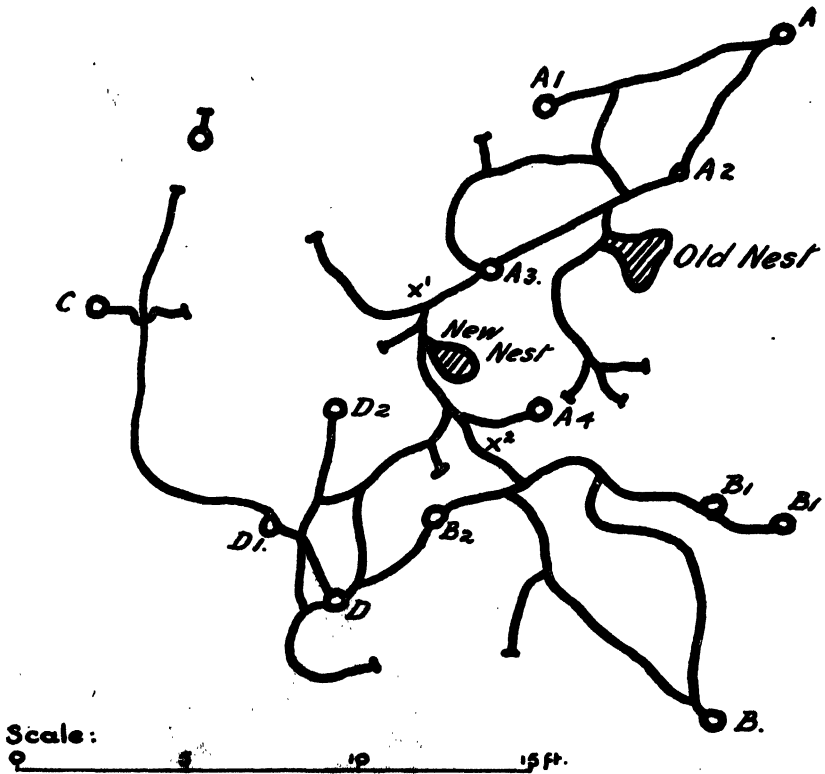
Sketches 1, 2 and 3 represent very simple colonies. The first dug and inhabited by *Geosciurus*, the second by *Suricata*, while the third was inhabited by *Cynictis*. Sketch 4 is typical of colonies of the more complicated nature.

The colony usually consists of a number of holes dug at an angle of about 30 to 40 degrees to the surface for a depth of two to three feet, according to the nature of the soil.

In cross-section the hole is roughly half-moon shaped approximately 3 inches high and 4 inches wide.

SKETCH 1.

Sketch-plan of a Simple Colony Inhabited by Geosciurus.



The colony, which was located on Trompsburg Commonage, was gassed with Cyanogas and dug up 44 hours later.

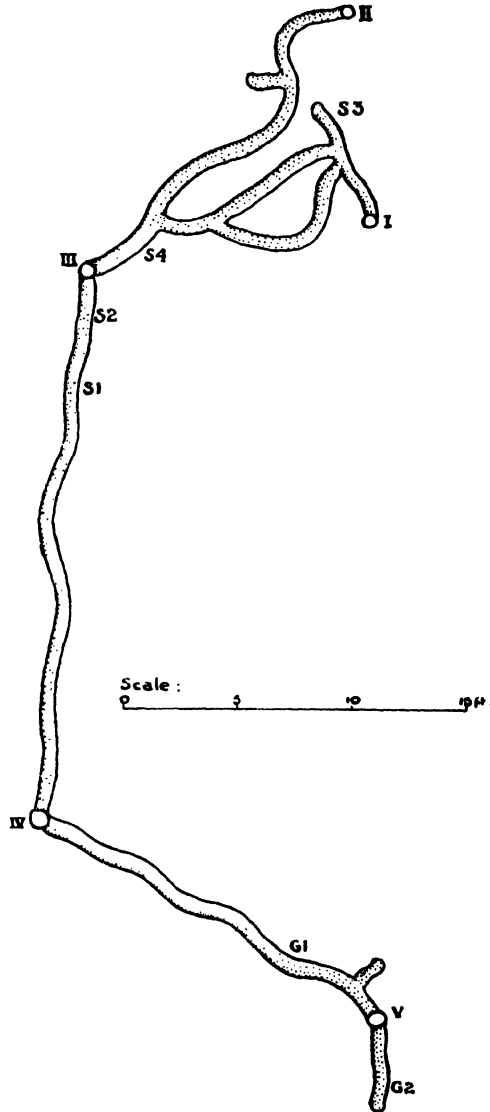
Reference:—

A dead *Geosciurus* was located at X¹, and a live one in a dazed condition at X².

A and B indicate the holes into which the gas was blown with a single action hand-pump.

SKETCH 2.

Sketch-plan to Scale of a Meercat Warren on Vryburg Commonage. Gassed with Cartridge Fumigators and dug up on 15.11.38.

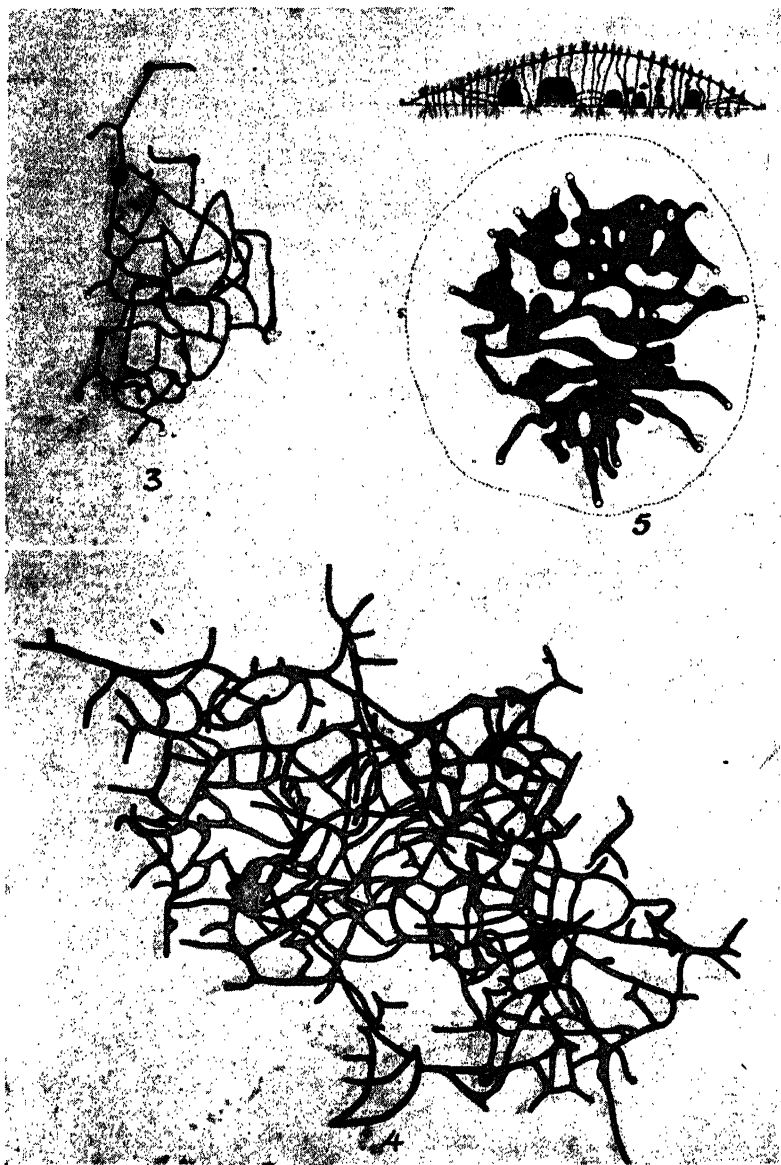


Reference:—

S1. indicates point where Suricates escaped.

S2 and S3, etc. indicate points where live Suricates were located.

G1 and G2 indicate where dead Geosciurus were located.



Sketch 3.—(Top Left.) Sketch-plan of a simple colony inhabited by *Cynictis*. The colony was dug up immediately after gassing, and a *Cynictis*, still alive, was located in the cul-de-sac at the top of the illustration.

Sketch 4.—(Bottom.) Sketch-plan of a typical meerkat colony of a more complicated nature. The colony was gassed after three *Cynictis* were seen to enter it, and then dug up. Six *Cynictis* and two *Geosciurus* were found dead in the burrows.

Sketch 5.—(Top right.) Sketch-plan and section of meerkat warrens in a "Trassiebos" mound. The large confluent chambers are due to constant caving in and removal of soft earth.

At more or less the same level underground, the tunnels are interconnected to form a maze or network. At intervals chambers are formed, lined with soft grass, forming the breeding and sleeping places. It has been found very frequently, when colonies were dug up, inhabited both by the squirrel and the yellow mongoose, that in the part inhabited by the former the bedding in the chambers consisted of fresh straw, while in the chambers occupied by the latter the bedding was old and in a decayed state or no bedding at all was present. It is evident, therefore, that the squirrel carefully prepares its breeding-chamber, while the yellow mongoose is satisfied with what it can obtain in sections vacated by the squirrel.

A very remarkable feature is that the tunnels are more or less on the same underground level, only occasionally does one find a tunnel passing under another, and thus failing to connect up or only connecting up when it has been down for a considerable distance, when it passes upwards again. The tunnels which do not connect usually end in a chamber. A feature, which was found to have an important bearing on the gassing (to be described later) of the colonies, was the presence of unconnected tunnels ending in cul-de-sacs, usually situated at the periphery of the colony and in an extension 30 feet or more long. Such a tunnel is well illustrated in sketch 3 extending towards the top. In a colony that has been exploded by dynamite and afterwards dug up, a tunnel thirty feet long was revealed, at the end of which a female suricate with a litter of five was detected.

There seems to be no limit to the size of the colonies. New holes and tunnels are added from time to time as the older portions are abandoned, or as the squirrel has to make room in its quarters for the yellow mongoose. Colonies, containing as many as a hundred or more openings, measuring fifty yards in diameter are frequently found. In such cases only a few of the openings on the periphery show signs of being in use.

Fresh excavations on new colonies or extensions to existent ones are only seen after rains, when the soil is soft and easily worked. Cleaning up the holes, which have partly caved in, also takes place at such times.

It can, therefore, easily be realised to what extent a colony situated in a favourable site and position, may increase by extension year after year. On the farm Beestekraal a colony has been dug up whose existence was known to the owner of the farm for at least fifteen years. The colony roughly measured 80' \times 105' and had about 90 openings.

As has been pointed out before, the *Geosciurus* prefers to dig its own colony, and will not, like the *Cynictis* take refuge in any kind of hole. The latter will only dig its own warren when it cannot find anything else to take refuge in. A pair of *Cynictis* was once found to have taken up their abode in an old caved-in anthear hole, to which they had made a side entrance. They also make

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use of refuse heaps, boulder heaps like those found as support for gate posts. Graves in neglected farm cemeteries are favoured by the *Cynictis* as the stones covering the loose soil in which they dig, afford a very good protection. Springhare warrens, both abandoned and inhabited, often harbour meercats too.

A very favoured abode is in the wind-blown sand mounds called "Trassie-bos" in Afrikaans. These mounds are formed by sand blown into and held by a thorny shrub *Acacia stolonifera*. As the sand-mound increases, the shrubs grow out and so catch more sand. Such mounds may reach a height of three to five feet and obtain a diameter of ten to twenty yards. The holes dug into the soft moist sand eventually collapse in dry weather, but the burrowing animal, being enticed by the soft soil and good drainage, persists in cleaning up and excavates large confluent chambers in the mound, the soil or sand roof being supported to some extent by the roots of the shrub, forming pillars or columns with sand packed around it. The burrows are therefore above the level of the ground. (Sketch 5.)

On the Trompsburg Commonage the town refuse-heaps deposited there were found to harbour *Cynictis*. One of the mounds selected for excavations was about 50 yards long and about 20 yards wide, and consisted mainly of coal-ash and refuse from dust bins. The average height of the ash above the ground level, where the openings and tunnels were made, was about 20 ins.

Slightly more than one inch of rain had fallen four days before the excavations were made. Three openings were freshly cleaned out, the ash being still moist. Two *Cynictis* were seen to enter into one of these on our arrival.

As the whole of the refuse mound could not be dug up, the warrens over an area of about 20 yards on either side of the freshly cleaned out warrens were gassed and the openings closed, and digging operations were started from the freshly cleaned-out warrens.

About half an hour after the time when the digging operations had been commenced, a *Cynictis* escaped from an opening which was 22 yards away from the starting point.

The ash was damp right through. The warrens extended obliquely down to the ground-level, but nowhere did they go beyond the ground-surface. The tunnels were very easy to follow in some places where the ash was comparatively solid. In others again the tunnels had partly caved in and were difficult to follow.

The network resembles an ordinary colony, but with the difference that the tunnels have less interconnections and are therefore longer. Several breeding chambers were uncovered, but in none of them was fresh straw or bedding found. This indicates that ground squirrels had dug or occupied these warrens.

DESTRUCTION OF THE VECTORS.

A. Methods Tried.

In order to devise the most effective and yet economical method of destruction of these animals, the following methods were investigated:—

1. Gassing the burrows with poisonous gases.
2. Trapping.
3. Destruction of the burrows and their inhabitants by means of explosives.
4. Baiting.

GASSING THE BURROWS WITH POISONOUS GASES.

The effects of the following poisonous gases were investigated:—

- (a) Hydrogen Cyanide.
- (b) Carbon Monoxide.
- (c) Sulphurous gases.
- (d) Heavy gases.

(a) *Hydrogen Cyanide.*

Preliminary experiments with gassing were conducted on colonies, both large and small, selected at random, which meercats were seen to enter.

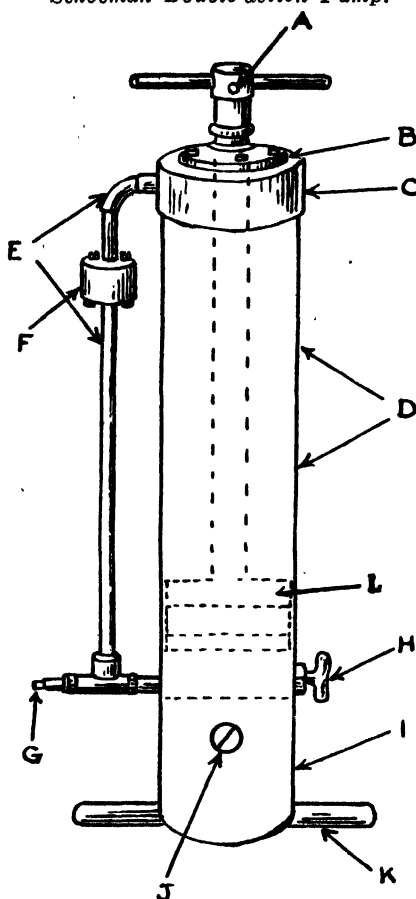
The gassing consisted of blowing finely powdered calcium cyanide dust (Cyanogas) with a hand-pump into the borrows. When this dust comes into contact with air it gives off hydrogen cyanide, leaving a residue of inert calcium hydroxide and impurities contained in the powder.

Two types of pumps were used, a single and a double action one. The single action pump works like an ordinary bicycle pump, but it is much larger, being about 3 inches in diameter. The air is blown through a chamber containing the powder, which is forced out in clouds.

The double action pump, known as the Schoeman pump (see Figure 1 and Illustration 8) forces the air on the downward stroke through a chamber containing the powder, which escapes from this chamber into the outlet in cloud-form. On the upward stroke pure air is forced into the outlet, thus giving additional force to the current of air created on the downward stroke. Both types of pumps have a control valve to regulate the cloud of dust blown out.

This pump has the advantage over the other pump, in that it not only works quicker, thus saving time, but that the powder-laden air is forced deeper into the burrows. The importance of this will be described later.

FIGURE 1.
Schoeman Double-action Pump.



A. Is the handle with an air-inlet for supplying the Cylinder D with air on the downward stroke of the piston.

B. Is a brass plate which compresses and expands a rubber ring on the inside which forms an air seal at the top of the cylinder, and is also fitted with an air slot through which air is sucked in on the downward stroke and forced into pipe E on the upward stroke.

E. Is the pipe and fittings which convey the upstroke air to the outlet G, and is fitted with a non-return valve, housed in F.

C. Is a brass strengthened bush.

G. Is the outlet nozzle to which a half inch hose is fitted.

H. Is the handle which controls a valve in the chamber I which regulates the powder supply to the outlet G.

J. Is an inlet fitted with an air tight cap for filling the chamber I with powder.

K. Is a footrest.

L. Is the piston, fitted with rubber piston rings, which expand when pressure is applied.

The principle on which the pump works is shortly as follows:—

On the downward stroke air is forced into the powder chamber I, where it disturbs the powder, which escapes through the valve controlled by H, into the outlet G. By turning the handle H, the amount of powder blown out can be either decreased or increased as required. On the upward stroke clean air is forced into the outlet G, through E, so as to provide some force behind the powder laden air forced out on the downward stroke.

(i) Method of Operations.

The powder control valve was adjusted so that a fairly heavy cloud of gas was blown out, but not so heavy as to allow a deposit of powder immediately in front of the loose end of the hose connected to the outlet.

The free end of the hose is inserted as far as possible into a hole, which is clean and well open. After insertion of the hose, the hole is filled up with earth, so as to prevent the escape of the gas. Pumping is then proceeded with. As soon as a perceptible cloud of powder emerges from a hole this is closed with earth. Pumping is continued through one hole until no more gas emerges. The hose is then inserted into another hole still open, and the process is repeated until all the openings in the colony are closed. The holes should be closed only when gas emerges, to allow free circulation of the gas and so avoid creating air pockets in the burrow.

Before any digging operations were commenced, the openings at which the gas was pumped into the colony were marked on the graph paper, adopting the same technique as was described in the previous chapter. The openings from which the dust was seen to emerge are indicated in the order in which it occurred, thus 1a, 1b . . . , 11a, 11b, etc., represents the order in which the holes were closed while pumping proceeded.

Digging operations were started, and the tunnels were traced in the same manner as described before.

Results of Experiments.

The results of the experiments are more easily followed when reference is made to the respective sketch plans of the colonies.

Colony 1. (Sketch 1.)

The colony was a fairly recently established one, situated in turt soil intermixed with lime pebbles. A single action pump was used and the gassing lasted for 15 minutes. The colony was dug up 4½ hours after the gassing was completed. A dead *Geosciurus* male was found at the point XI, and a live female in a somewhat dazed condition at the point X2.

Colony 3. (Sketch 3.)

As indicated in the sketch this was a fairly simple colony, which was dug up immediately after gassing. A live *Cynictis* was found in the cul-de-sac at the top of the illustration.

Colony 15.

This was a fairly large colony. Several meercats were seen to enter the burrows. It took about thirty minutes to complete the gassing, using a double action pump. Excavations were started immediately after gassing. Dead mongooses were found at two points while live ones were located at two other places. The one live mongoose was in a semi-conscious condition. Two dead squirrels were dug up in different parts of the colony.

Colony No. 122.

This experiment was conducted by the Zoological Survey Staff on a colony on the farm Beestekraal, Hoopstad district, on 3rd December, 1937. The colony was between 15 and 20 years in existence according to the owner of the farm. This was a very large and complicated colony, measuring 105 ft. by 80 ft. Five squirrels were seen to enter into the warrens previously. Before

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gassing, all the old and disused openings were reopened to allow for better circulation of the gas. The dusting operations lasted 70 minutes, one double action pump being used.

When the colony was dug up seven dead squirrels were found. The depth of the tunnels ranged from 1 to 3 feet.

Colony No. 112. (Sketch 4.)

Date 16.12.37. (By courtesy of the Zoological Survey). On this occasion Colony No. 112, Beestekraal, Hoopstad district, was selected. It was formerly a springhare (*Pedetes capensis*) colony, but at the time of gassing inhabited by meercats. The soil is of a deep sandy nature and was somewhat moist, 56 ins. of rain having fallen on the 14th. The disused and fallen-in openings were found reopened. The actual times of dusting were: A.—7 min., B.—5 min., C.—3 min., D.—3 min., E.—4 min., F.—2 min., G.—2 min., H.—3 min. Total time, 31 minutes.

The depth ranged from 1 to 4 feet. Six dead mongooses were found, one each at points X1, X4, X5 and two juveniles at X2. At points G1 and G2 dead squirrels were found.

Colony 39. (Sketch 5.)

An experiment was conducted on a "trassiebos" colony No. 39 Beestekraal, Hoopstad district, 30.11.37. The colony measured 30 ft. in diameter. Two meercats were seen to enter the colony before the gassing operations. On excavations two dead *Cynictis* were unearthed at the points indicated.

Discussion of Results.

Ten colonies, ranging from very simple ones to the most complicated imaginable including a trassiebos mound, were gassed with Cyanogas and dug up at various intervals after gassing. The results obtained were on the whole satisfactory and encouraging. In all cases, except in three, all the meercats dug up were dead. In two of the three cases live meercats were found in comparatively small and simple colonies. Of the four animals, that were still alive, three were found in blind tunnels or cul-de-sacs. It is obvious, that in such cases the force of the air current is not strong enough to force gas into the blind passages. In the case of the *Geosciurus* (Colony 1) found in a dazed condition in an open tunnel, its escape may be due to the fact that insufficient gas penetrated to the point X2 when gassing took place from A; and when gassing was commenced at B, a blind tunnel was actually formed as the openings on the far side from B had been closed.

Conclusion.

(1) It is possible to destroy all the meercats in a colony even in very large and complicated ones by means of Cyanogas fumigation.

(2) In some instances when the burrowing animals have taken refuge in blind tunnels or cul-de-sacs, the gas fails to reach and destroy them. Especially is this the case in those tunnels which extend for great distances up to 30 feet.

(ii) The Minimum Lethal Concentration (M.L.C.) of Hydrogen Cyanide for Meercats.

At this point it became necessary to find out what minimum concentration of HCN was best suited to the purpose in view, and also to determine for what length of time such a concentration could, or had to, be maintained in warrens.

For this purpose a lethal box of wood was constructed, with inside dimensions of 52·1 by 61 by 26·7 cms., with a small inlet door. About two-thirds of one side was cut away and replaced with ordinary clear glass plate. On the top of the box, a hole 1½ in. in diameter, fitted with a tight-fitting rubber stopper, was made through which the Calcium Cyanide was to be introduced.

The testing and controlling of the HCN concentration was done as follows: A table later published by Steyn (1939) was used, showing the sensitivity of the picrate paper test (Guignard Test) for Hydrocyanic acid, i.e., the time taken to discolour picrate paper in various concentrations of HCN. From the data contained in this table a graph was drawn of the concentration against the time taken to discolour the paper. See graph No. 2.

For the purpose of the experiment a number of *Cynictis* were caught alive, some in a net placed over an open warren while the colony was smoked or dug up, others by means of traps.

To determine the effect of various concentrations of HCN on the animals, an animal was introduced into the box through the opening for the purpose, and measured amounts of Cyanogas dust were lowered with a spoon into the box and distributed into the air by giving a sharp blast of air on the spoon with an ordinary motor-type pump. The amounts of Cyanogas dust used were measured approximately in an ordinary graduated 10 c.c. cylinder—for three very good reasons: (a) no scale was available in the field, and (b) even if available it would have been unwise to expose the powder to the air for any length of time while it was being weighed, and (c) since the concentration of HCN was being estimated by the picrate method, the exact amount of dust was not of immediate importance.

*Experiments on the Minimum Lethal Concentration (M.L.C.) of
Hydrogen Cyanide for Meercats.*

The lethal chamber, described above, was used throughout these experiments, its capacity was 84,852 cub. cms.

Experiment I.—Beestekraal, 14.1.38.

Object.—To determine the reaction of a *Cynictis* to a concentration of 1 : 7,680 of HCN.

Amount of Ca (CN)₂ introduced.—Approximately 4 c.c. of loose powder.

The lapse of time from the time of insertion of Animal into Box.	Time taken for Picrate Paper to Discolour.	Equivalent Concentration of HCN.	Remarks on condition of Animal.
1 min. 6 secs.	45 secs. . . .	1 : 7,680	Falls over.
2 min. 41 secs.	—	—	Shallow breathing.
3 min. 26 secs.	—	—	Stopped breathing. Dead.

STUDY AND CONTROL OF THE VECTORS OF RABIES.

Experiment IV.

Object.—To determine effect of a low concentration of HCN on a *Cynictis*.

Amount of Ca (CN)₂ introduced.—The box was cleaned of all obvious dust. The Picrate paper took 10 minutes to discolour; i.e., a concentration of 1:5–800,000.

The lapse of time from the time of insertion of Animal into Box.	Time taken for Picrate Paper to Discolour.	Equivalent Concentration of HCN.	Remarks on condition of Animal.
3 min.....	—	—	Sneezing.
5 min.....	—	—	Sleepy appearance.
6 min.....	—	—	Sits on hind-quarters like a dog.
8 min.....	—	—	Apparently no effect.
10 min.....	—	—	Apparently no effect.
13 min.....	—	—	Apparently no effect.
		2 c.c. of Ca (CN) ₂ blown into box.	
1 min.....	—	—	Salivation.
2 min.....	—	—	Sneezing, salivating, and masticating movements.
3 min.....	—	—	Shakes head. Salivating.
6 min.....	—	—	Profuse salivation; lies down.
8 min.....	—	—	Gets up and lies down again.
9 min.....	—	—	Inco-ordinated movements; respiration accelerated. Sneezes and rolls over.
11 min.....	—	—	Dyspnoea.
12 min.....	—	—	Twitching of the muscles. Cheyne-Stokes respiration gasps at intervals of 8, 5, and 3 secs., irregularly.
15 min.....	—	—	Shivering of head; hair rises on tail.
16 min.....	—	—	Pupils dilated; shallow gasping, at 18–16–22–18 to 30 secs.
19 min.....	2 min. 30 sec.	1:31,200	Hair subsiding on tail; shallow gasps at 30–40 secs.
22 min.....	—	—	Pupils dilated $\frac{1}{2}$; dead.

Experiment V.

Object.—To test effect of HCN on *Geosciurus*. (Animal was bleeding from nostrils).

* *Amount of Ca (CN)₂ introduced.*—None added, Picrate test, 3 minutes, i.e., a concentration of 1:43,800.

The lapse of time from the time of insertion of Animal into Box.	Time taken for Picrate Paper to Discolour.	Equivalent Concentration of HCN.	Remarks on condition of Animal.
5 min.....	—	—	Apparently no effect.
6 min.....	—	—	Slight uneasiness.
9 min.....	—	—	Attempts to lie down.
14 min.....	—	—	Apparently no effect.
		2 c.c. Ca (CN) ₂ introduced.	
1 min.....	—	—	Salivation.
2 min.....	—	—	Convulsive movements.
3 min.....	—	—	Lying on side and making running movements. Breathing spasmodically.
4 min.....	—	—	Frequent deep gasps, salivation stopped. Testes retracted. Hair on tail raised fanwise.
5 min.....	—	—	Occasional prolonged inspiration. Hair on tail subsides.
6 min.....	—	—	Hair smoothes down; heart beats fast; gasps at 30 secs. intervals.
7 min.....	—	—	Gasps at irregular intervals.
10 min.....	2 min.....	1:22,800	Heart beat slower; inspiration prolonged.
11 min.....	—	—	Heart beat hardly perceptible; inspiration slow.
13 min.....	—	—	Faint shallow gasps.
14 min.....	—	—	Heart-beat stopped. Dead.

STUDY AND CONTROL OF THE VECTORS OF RABIES.

Experiment VI.—Philip, 25.5.38.

Object.—To observe reactions of two animals under approximately identical conditions. Two *Cynictis* were introduced, marked A and B.

Also the effect of moisture: About two ounces of water were poured into the box, and air from a motor tyre pump was played over it, to evaporate it.

Amount of Ca (CN)₂ introduced.—Not measured. The Picrate test was 5 minutes, i.e., 1:180,000.

The lapse of time from the time of insertion of Animal into Box.	Time taken for Picrate Paper to Discolour.	Equivalent Concentration of HCN.	Remarks on condition of Animal.
9 min.....	5 min.....	1:180,000	Apparently no effect.
		More Ca(CN) ₂	blown into box.
1 min.....	—	—	Apparently no effects.
3 min.....	—	—	A.—Sneezed; uneasy, walking about. Fell down on undispersed powder.
			B.—Apparently no effect. In far corner of box.
4½ min.....	—	—	A.—Deep respirations.
			B.—Apparently no effect.
5 min.....	—	—	A.—Violent spasms and kicking. Hair on tail rising slowly. Accelerated gasps.
			B.—Apparently no effect.
7 min.....	—	—	A.—Occasional deep inspirations.
			B.—Twitching of abdomen. Respiration accelerated; walks about. Comes near to the gas. Unsteady, gets up. Short shallow inspirations.
11 min.....	1½ min....	1:16,100	A.—Pupils dilated.
			B.—Down, but still able to lift itself.
14 min.....	—	—	A.—Intermittent breathing, shallow.
			B.—Respiration shallow and accelerated; intermittent deep inspiration.
17 min.....	2 min.....	1:23,000	A.—Hair on tail subsiding. Dead.
			B.—Same as before.
24 min.....	—	—	B.—Taken out of box and put in fresh air. Corneal reflex absent.
2 minutes after being taken from the box	—	—	B.—Deep gasp. Respiration accelerated, corneal reflex faint.
10 min.....	—	—	Pulse accelerated; twitching of toes; forced expiration.
12 min.....	—	—	Opening and closing of eyelids. Muscula control gradually being regained.
21 min.....	—	—	Comes to a sitting position. Falls over again. Violent spasms.
26 min.....	—	—	Eyes closed. Respiration deep and forceful. Pulse accelerated.
30 min.....	—	—	Able to rise, looks round, very weak.
31 min.....	—	—	Attempts to run, but falls over. Gets up. Animal recovering rapidly.

Experiment VII.—Beestekraal, 26.1.38.

Object.—To test effect of a higher concentration of HCN on a *Cynictis*, under same conditions as previous experiment.

Amount of Ca (CN)₂ introduced.—1 c.c. loose dust.

The lapse of time from the time of insertion of Animal into Box.	Time taken for Picrate Paper to Discolour.	Equivalent Concentration of HCN.	Remarks on condition of Animal.
5 min.....	—	—	Sleepy appearance. Head between forelegs.
10 min.....	—	—	Sneezing; eyes rolling. Expiration forced.
15 min.....	—	—	Respiration regular, but shallow.
20 min.....	6 min.....	204,000	Same as before.
25 min.....	—	—	Unsteady in sitting position. When box tilted falls over, but rights itself.
30 min.....	—	—	Sits with head hanging, as if sleeping.
Ca (CN) ₂ introduced .7 ccs.			
1 min.....	1 min.....	1:10,300	Head sinking.
2 min.....	—	—	Spasms; stretching of limbs; gasps.
3 min.....	—	—	Respirations imperceptible. Dead.

Discussion of Results.

The concentration of Hydrogen Cyanide which gave the optimum result, killing the experimental animals in less than four minutes were 1 : 7,700 and higher. Desired effects were obtained with concentrations of 1 : 12,000 to 1 : 24,000 killing the experimental animal in 9 to 10 minutes. A concentration of 1 : 31,200 killed the experimental animal in slightly over 19 minutes, while a concentration 1 : 43,700 failed to have the desired effect.

It is estimated that a concentration of Hydrogen Cyanide of 1 : 31,200 would kill meercats in a confined air space, but for practical purposes in warrens the aim should be to obtain concentrations of between 1: 30, - 24,000 or higher, and that concentrations of 1 : 36,000 or lower would not be sufficiently strong to kill the animals in their burrows. Theoretically therefore the concentration to be aimed at both from the point of view of economy and of rapid destruction of the animal must lie between the ranges of 1 : 24,000 and 1 : 30,000.

(iii) The Concentration of Hydrogen Cyanide in the Burrows of Meercats.

In view of the fairly high concentration of Hydrogen Cyanide, which is fatal to meercats and the comparatively big length of tunnelling in the maze constituting the colony, it is obvious that success in fumigation depends largely on the concentration of Hydrogen Cyanide attained in the burrows, and on the length of time this concentration is maintained in the burrows.

STUDY AND CONTROL OF THE VECTORS OF RABIES.

In order to investigate this, suitable colonies of different types were selected for the purpose. The openings were marked on graph paper in the usual way. The openings on which the tests were to be performed were selected in such a way as to be representative of the colony and as evenly distributed as possible. These openings were opened up to a depth of about 18 ins. to make sure that single tunnels were being dealt with, and to obtain their representative perimeter. This was also an advantage in the operations as the firm and damp soil facilitated the insertion of the apparatus.

Into these selected and prepared holes, white glass cylinders 3 ins. in diameter and about 12-18 inches long were inserted, being as near as possible to the diameter of the tunnels. These cylinders resembled long winchester bottles, with the bottom knocked out, and in fact such bottles had to be pressed into service also. The open end was pushed into the burrow and the neck end, with the rubber stopper, protruded out and enabled one to insert the test-paper and see its turn of colour. The cylinders were securely packed with damp soil so as to prevent any escape of gas. The rubber stoppers were withdrawn, and the positions of the cylinders were marked on the ground plan with Roman numerals.

Gassing operations were then begun in the usual way. As soon as puffs of dust emerged from a cylinder the rubber stopper was replaced, the opening being thus sealed up in the same way as if it were closed with earth. The sequence in which the dust emerged from the cylinders was recorded in the usual manner.

At definite intervals and more or less in rotation the concentration of Hydrogen Cyanide in the cylinders was tested, by inserting picrate test papers, fixed on thin pieces of wire through the stoppered openings and thus visible through the glass. Care was taken to insert the papers and to replace the stoppers as quickly as possible so as to prevent the escape of gas. The time taken to discolour the picrate papers was recorded for each cylinder. The interval between testing was fixed arbitrarily at 15 minutes, as this interval allowed just sufficient time to do the round of tests and to obtain the greatest number of tests for a definite period.

The corresponding concentration of Hydrogen Cyanide was obtained from the curve by reading the length of time in which the picrate test paper took to discolour. This information was recorded for each cylinder in a colony. Graphs, for each colony, were then plotted of the Hydrogen Cyanide concentration against the time interval, after the gassing had been completed.

The colonies were then dug up and details as to inhabitants, etc., recorded in the usual way.

Samples of soil were collected at the depth of the tunnelling, to determine the moisture content of the soil. This was done in the following way. About 500 grams of sand were weighed and heated in an oven at a temperature of approximately 230° F. until constant weight was attained, when the percentage loss of weight taken to be moisture, was calculated.

Experiment I.

This was conducted on a "Trassiebos" colony on the farm Wintershoek, which adjoins Beestekraal in the Hoopstad district. The gassing took 14 minutes to complete. The glass cylinders, after the tests were completed, were left in position over night, and a test on each on the following morning revealed a trace of Hydrogen Cyanide. Incidentally a dead *Cynictis* was found in cylinder No. 11 in the morning, and a warren closed with sand was found reopened.

Experiment II.

The colony selected was a typical colony in soft sandy soil on the sandbult at Beestekraal. Seven meercats were chased into the colony. The gassing took place from five different holes, and the times of dusting from the different holes were 13, 10, 6, 8 and $\frac{1}{2}$ minutes.

On excavating the colony six dead suricates and one dead mongoose were recovered. A live *Cynictis* was discovered in a blind tunnel four feet long. The soil could be moulded by hand with fairly hard pressure. The moisture content was 2.6 per cent.

Experiment III.

Colony No. III on Beestekraal was selected for this experiment. The colony was of the same nature and soil as the preceding one. Three yellow mongooses entered the colony. The times of gassing were 9, 13, 1, and 9 minutes respectively. One hole was found to be closed. From Cylinders Nos. III and VII no Cyanogas emerged, and on excavations the warren of No. III was found to be partly filled with loose sand, while for No. VII no obvious cause could be found. Two dead mongooses were found.

The moisture content of the soil was 2.8 per cent. The soil could be moulded with the hand on pressure.

Gassing with Compressed Air.

The rate at which an air current flows through a tunnel is resisted by opposing forces created by:—

- (a) the length of the airway;
- (b) the perimeter of the airway;
- (c) the degree of roughness of the surface;
- (d) and the number and angles of the turns in the airway.

It is perfectly clear, that the comparatively small force created by an ordinary double action hand-pump is soon reduced to a negligible amount by diffusion in the length of tunnelling formed by the network in a colony. The comparatively small perimeter of the outlet pipe to that of a tunnel and the numerous turns sometimes at acute angles, combined with the roughness of the surface of the warrens, would further retard the force of the air current created by the pump.

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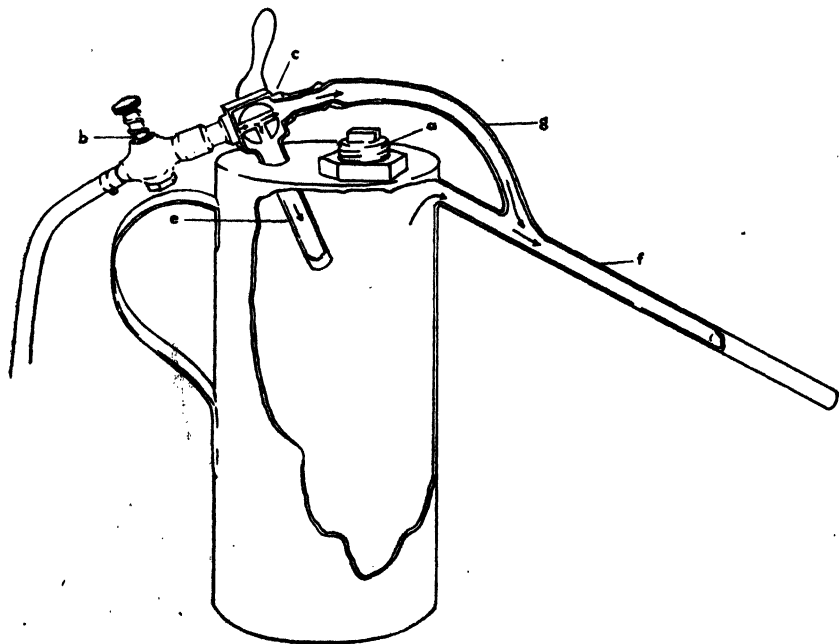
It was considered that the failures in many instances were due to poor distribution of the dust along the deeper tunnels, and that this might be overcome by using a jet of compressed air, which would create greater force and volume to overcome some of the retarding influences. Further, that in the case of blind tunnels or cul-de-sacs the greater velocity of the air-current would create a partial vacuum in them, and that when the air current ceased, air laden with cyano-gas powder would be sucked into them, and so kill meercats which might have taken refuge in these.

A small Curtiss Pneumatic compressor, driven by a "Mar-vil" two stroke engine, mounted on a cylindrical pressure tank 30 ins. long and with a diameter of 14 ins. was acquired. The tank was tested to a pressure of 150 lbs. per sq. in. This plant was mounted on a donkey cart for transport purposes on the veld.

A special insufflator designed by Dr. Thomas was used in connection with the compressed air outfit.

FIGURE 2.

Thomas Insufflator.



A special insufflator designed by Dr. Thomas and used with compressed air for gassing meercat burrows.

For description see text.

Description of the Thomas Insufflator.

(See Figure 2 and Illustration 9.) The insufflator consists of a can, 10 ins. deep, with a diameter of 5 in., fitted with a handle similar to the ear of a cup. On the top of the can is an opening (a) fitted with a screw cap for filling the insufflator with powder. The insufflator is connected to the pressure tank by

ten yards of pressure hose-pipe, which is connected at the point (b), where a spring release-stopper is fitted. At the point (c) a bifurcation exists in the air-supply tube into which a three-way stopcock is housed with a hand-lever. One tube (e) leads into the can for about 3 inches at an angle, while the other (g) forms a deviation which joins the outlet tube (f). A short length of hose-tubing is connected to the outlet (f) for insertion into the warren.

When the spring release-stopper is pressed (b), compressed air enters along the tube, and by manipulating the lever of the three-way stop-cock (c) the air-flow into the can can be regulated, while the rest of the air escapes along the bye-pass (g) into the outlet tube (f). The air laden with powder escapes into the outlet (f). The concentration of powder blown into the warrens can therefore be very accurately regulated.

Plan of Experiments.

The following two experiments were planned to serve a double purpose, (a) to serve as a repetition of the Hydrogen Cyanide concentration test conducted on Beestekraal, and (b) to compare the efficiency of the compressed air outfit for fumigation purposes with that of the ordinary double action hand-pump.

The procedure adopted with the compressed air outfit was exactly as that adopted with the hand-pump.

Experiment IV.

For the purpose of this experiment a colony (A) was selected on Bestersrust adjoining Philip in Hoopstad District. The colony was situated on a high bank on the side of a pan. The soil, although sandy in nature and fairly moist, was hard lower down owing to clay. On the morning of 23rd of May, 1938, after the usual preliminaries of plotting and insertion of the cylinders, etc., the colony was gassed with compressed air, and the necessary picrate tests were performed. After the tests had been completed, the cylinders were taken out and the openings filled in with earth.

The following morning all the holes were reopened by hand and the cylinders were inserted in the same positions as the previous day. Tests were taken in the cylinders. When these proved negative for HCN, two squirrels distinctively marked were introduced, one each from two different holes. The gassing with the hand-pump was then proceeded with from the same two holes and in the same sequence as the previous day.

Gassing was commenced at 9 a.m. and was completed at 9.30 a.m. The picrate tests were then repeated as on the previous occasion, and lasted until 1 p.m. At 10.50 a.m. two more squirrels with one injured foot each, having been caught in a trap, were inserted through cylinder I.

The colony was dug up when all the cylinders except No. I gave negative tests.

Results of the Experiment.

(1) On the morning of the second day before the gassing with the hand-pump was undertaken, two holes in the colony were found open. (2) When the two squirrels were introduced through cylinder I at 10.50 the picrate test paper took 30 seconds to discolour, and

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after the introduction the time elapsed was only 20 seconds. (3) Spent Cyanogas powder was found at a point between one opening and cylinder VII, and loose sand was found at a point near the cylinder, and partially obliterating the tunnel. This explained the negative test at cylinder VII, where only a trace of Hydrogen Cyanide was recorded. (4) The following dead animals were found: At cylinders I and III stiff carcasses of *Cynictis* were found, while at cylinder II a fresh carcase of the same species of animal was discovered. It must be remembered that no *Cynictis* were introduced. Four carcasses of *Geosciurus* were found.

The carcasses of the two marked squirrels were found near the openings, through which they were introduced, those introduced through cylinder I at 10.50 a.m. were found near the cylinder. A fresh unmarked carcase of a *Geosciurus* was also found.

Experiment V. 3.5.38.

The previous experiment was repeated in every detail on the same farm, on a very large colony (B) of which only a portion seemed to be inhabited. As the openings in that portion had fallen in and showed no signs of meercat activity, to save unnecessary digging, a trench, 40 inches deep, was dug right across the colony separating the used from the unused section. Several tunnels were found opening into the trench, all at more or less the same level, from 12 to 18 inches from the top of the trench. The trench thus completely intersected all tunnels leading into the disused section. These holes were plugged with clay. Three *Cynictis* caught in traps were introduced into an opening. The gassing and testing were completed at 5.37 p.m. The cylinders were left in position over night. At 8.30 the following morning two *Geosciurus* were introduced. None of the openings was found reopened during the night.

After all the openings had been carefully reopened by hand, gassing was repeated with the hand-pump and the picrate tests were made.

Results.

The following carcasses were recovered:—

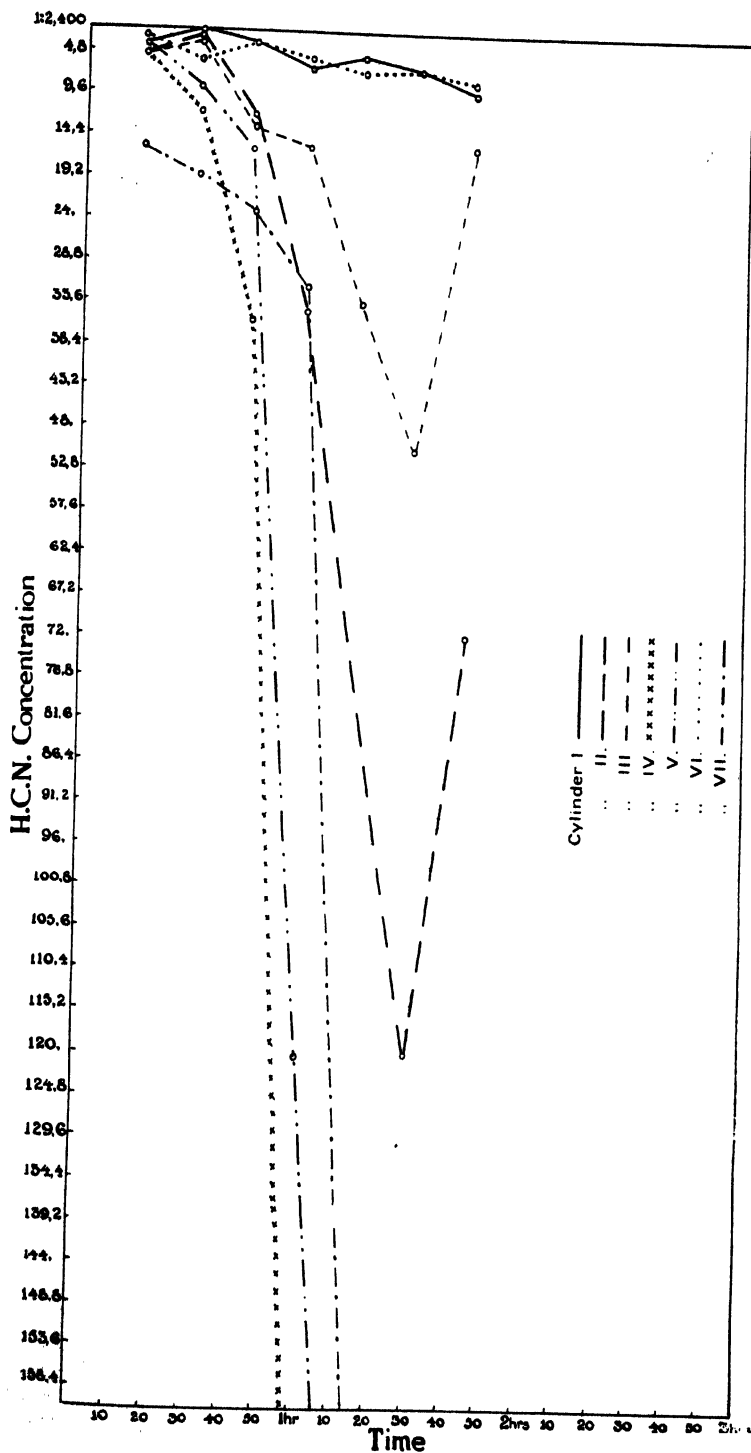
1. Two *Cynictis*, both stiff and marked.
2. Three *Geosciurus* carcasses, two of which were fresh and marked, while one was stiff and unmarked. The carcase of the third *Cynictis* which had been introduced the previous day was not recovered.

Discussion of the Results on the HCN Experiments.

Experiment I, "Trassiebos". Graph 3.

(a) High concentrations of Hydrogen Cyanide were maintained in openings I and IV for at least 1½ hours.

(b) Within 1 hour from the time of completion of gassing the concentration in four openings dropped to below 1 : 30,000.



Graph No. 3.

Experiment I.

Colony in a "Trassiebos" mound on Beestekraal: 14.1.38.

HCN concentration in the warren using a hand-pump.

(c) In two openings, II and III, the concentration increased at the same time, in No. III the concentration reached 1 : 15,600.

The colony was unfortunately not dug open to see the results of the gassing. The explanation for the discovery of the *Cynictis* in Cylinder No. II can only be speculative. It is thought, that the *Cynictis* was prevented from escaping into the colony by our presence, and that soon after we had departed, and everything seemed safe it opened one hole and entered, and disturbed some of the Cyanogen powder that had settled. In its endeavours to escape the *Cynictis* was trapped in the cylinder. This explanation is quite acceptable, for as can be expected, from the structure of a "Trassiebos" colony consisting of big chambers (even if the animal had travelled through chambers connected with openings I and VI, where the concentration remained high 1 : 7-9,000) it could still have reached the place where it was found, for such a concentration is fatal in 105 seconds only.

Experiment II. Graph 4.

(a) In cylinder III a negative test was recorded, in spite of the fact that it was the first hole from which the gas emerged when dusting. The gas emerged after 1 minute.

(b) A concentration of 1 : 30,000 was maintained in five of the test tunnels for $2\frac{1}{2}$ hours after completion of gassing of the colony. In one tunnel, No. V, the comparatively high concentration was maintained for $3\frac{1}{4}$ hours. The high concentration was the result of a large amount of calcium cyanide deposited in the vicinity of the test cylinder.

(c) The fact that a live *Cynictis* was found in the blind tunnel, was evidently due to the animal having escaped contact with the gas while there.

Experiment III. Graph 5.

(a) The sudden decrease in the Hydrogen Cyanide concentration in the opening I was due to the small amount of cyanogen that was precipitated at that point, on account of its distance from where the dusting took place.

(b) A negative test was recorded at cylinder III as can be expected, as the tunnel was partially fitted with sand. The negative test in VII cannot be explained.

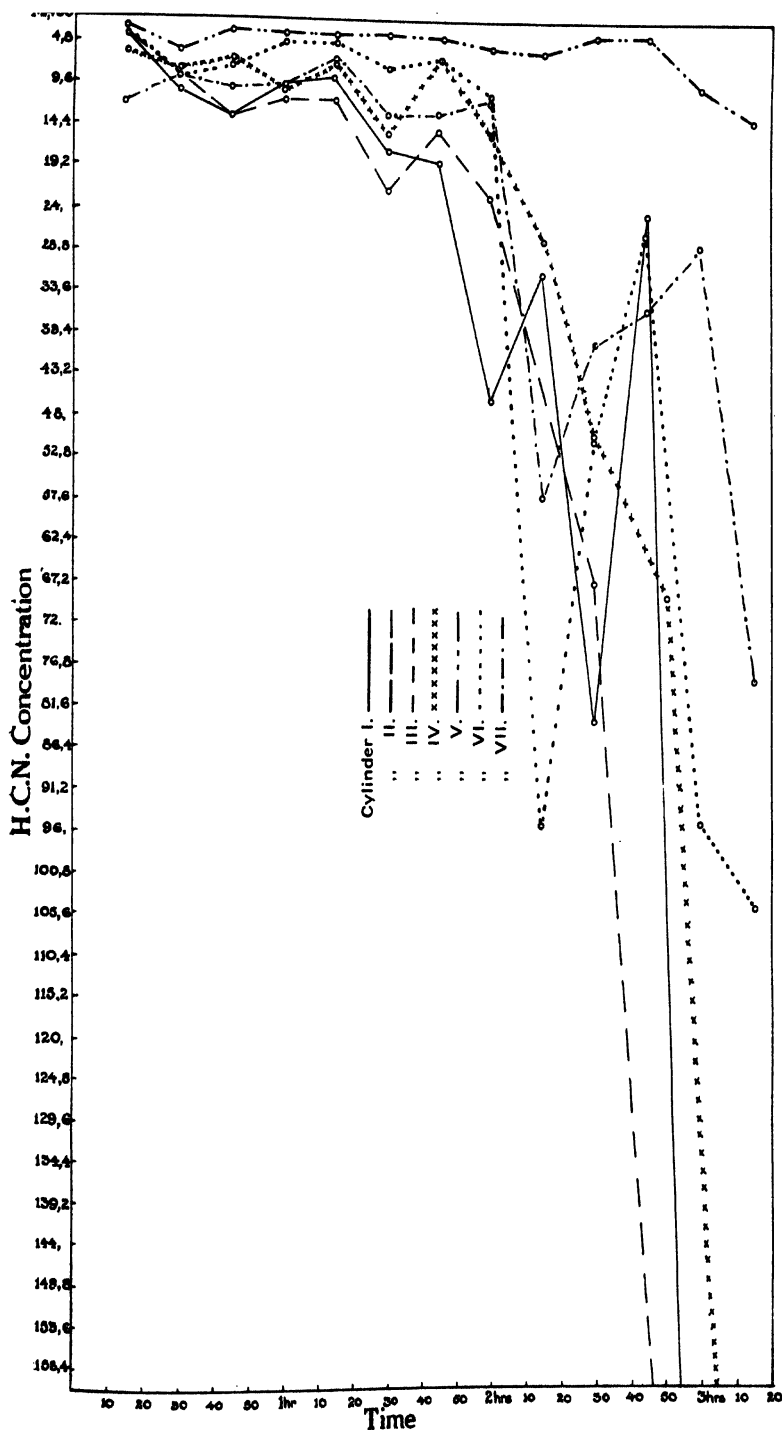
(c) The test was not continued for a long enough period.

Experiment IV.

(1) *Gassing with hand-pump.* Graph 6. Colony A.

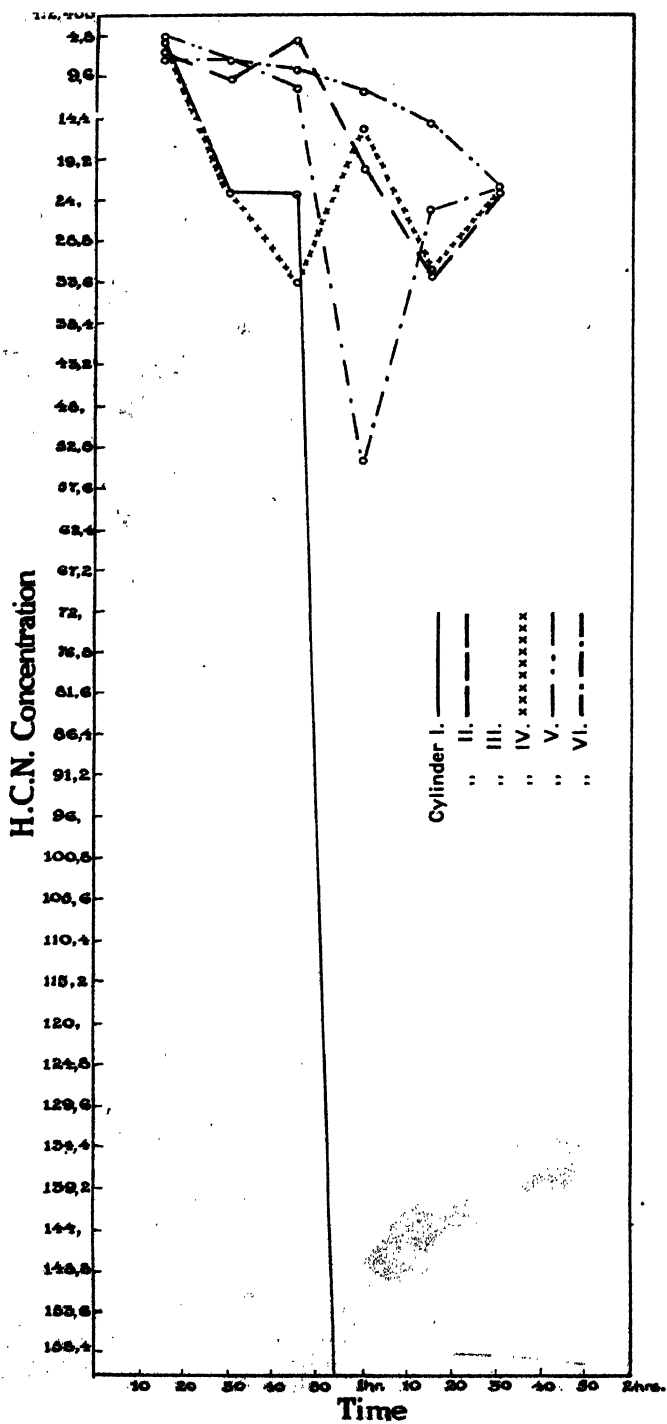
(a) In three of the cylinders a high concentration was maintained for more than two hours.

(b) In two cylinders No. VI and VII only a trace of Hydrogen Cyanide was recorded.



Graph No. 4.
 Experiment II.
 Colony in sandbult on Beestekraal.
 HCN concentration in meercat burrows using a double action pump.

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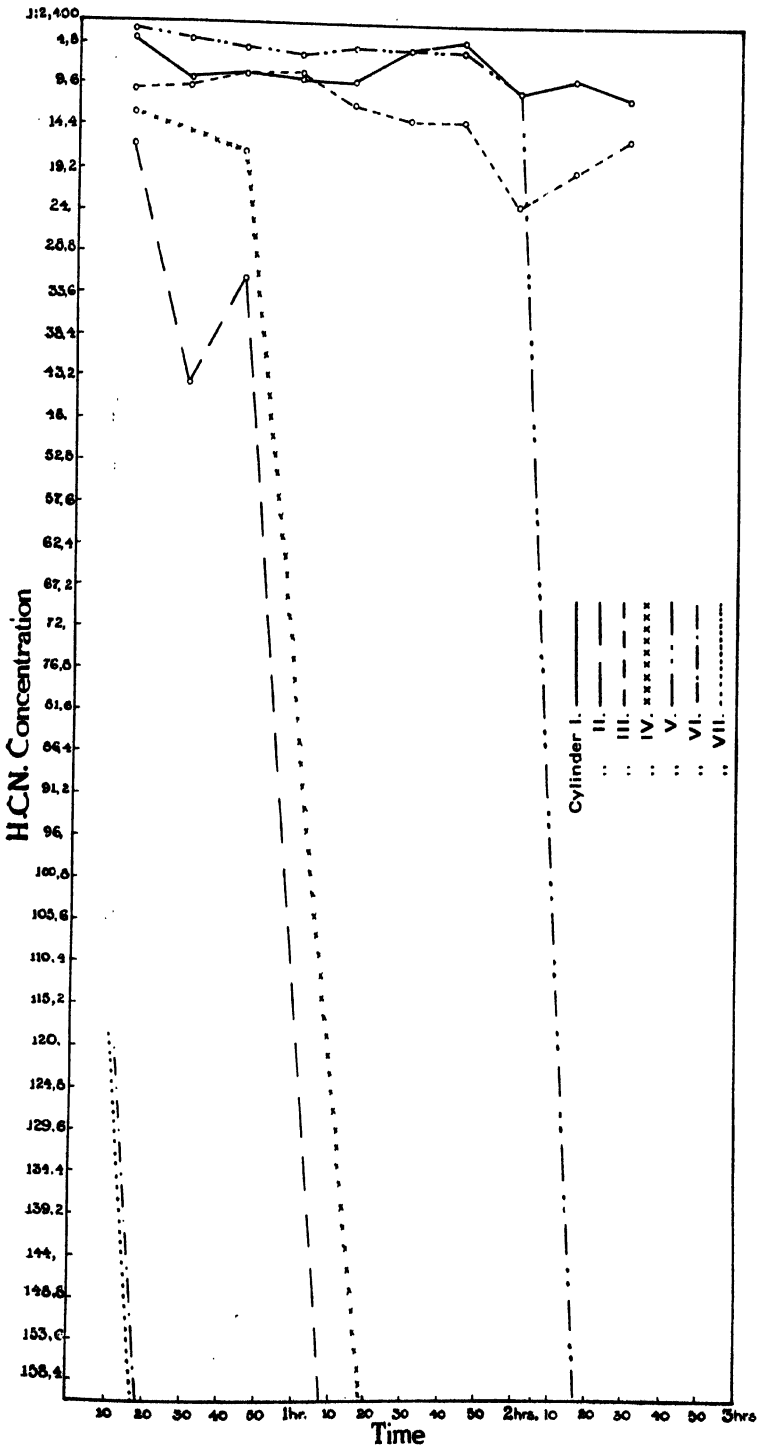


Graph No. 5.

Experiment III.

Colony III: Beestekraal: 15.1.38.

HCN concentration in meercat burrows using a hand-pump.



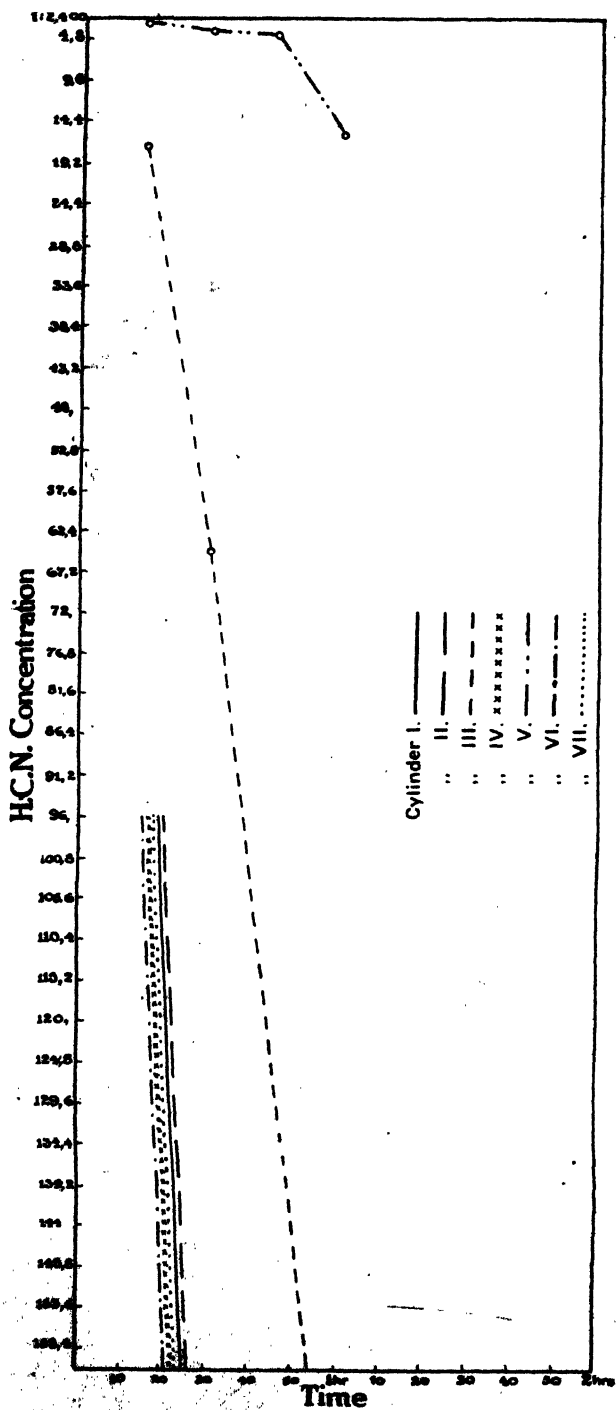
Graph No. 6.

Experiment IV.

Colony A: Bestersrust: 4.5.38.

HCN concentration in burrow when hand-pump was used.

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Graph No. 7.

Experiment IV.

Colony A: Bestersrust: 3.5.40.

HCN concentration in burrow when compressed air was used.

(c) A slight rise in the concentration was recorded in No. I after the two squirrels had been introduced. The rise in concentration was obviously due to disturbance of the precipitated cyanogas by the animals.

(2) *Compressed Air.* Graph 7.

(a) In contrast to the high concentration produced in 5 cylinders when using the hand-pump, concentrations of lower than 1 : 96,000 were produced in five cylinders.

(b) In two cylinders only was a concentration of higher than 1 : 24,000 recorded. In No. III it was maintained for 20 minutes only, and in one, No. V, a high concentration was maintained for more than 1½ hours.

(c) It was further noticed that the gas did not emerge from the same openings and in the same sequence, when gassing was done from the same hole and using the hand-pump and compressed air. While gas emerged when the compressor was used at an opening, it would not emerge from the same opening when the hand-pump was used, so that gassing had to be resumed at a different opening.

The same is noticed to a lesser extent in Experiment V. It is doubtful whether this variation in air currents produced had any effect on the HCN concentrations in the warrens.

Experiment I. Colony B, Bestersrust, Graph 8. Hand-pump.

(a) In 5 cylinders a high concentration of HCN was maintained for 2½ hours.

(b) In two cylinders (VII) and (VI) a concentration of 1 : 24,000 was maintained for 30 minutes only. This is obviously due to a small deposit of dust in the corresponding tunnels, owing to the distance away from the openings where the dusting took place.

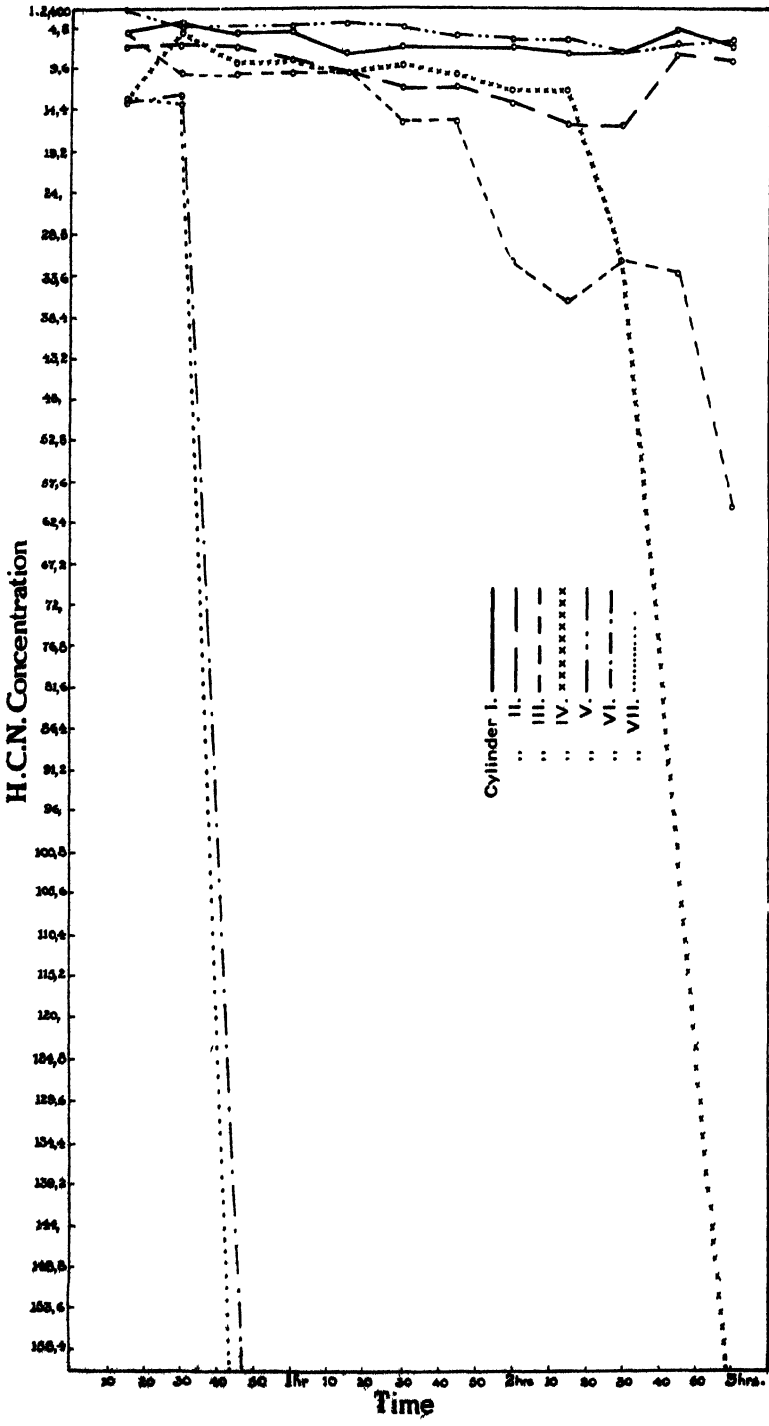
Compressed Air. Graph 9.

(a) Better results were obtained in this case with compressed air than in the previous experiment. The longer interval, which elapsed between the beginning of the gassing and the testing in the previous experiment, was a contributory factor. The colony in the previous experiment was very much larger than in this experiment.

(b) In two cylinders, I and IV, a high concentration was maintained for some time. This was obviously due to large amounts of deposits of cyanogen in the corresponding tunnels. Gassing was done through cylinder I and IV (which although situated some distance from the hole where gassing took place) were connected with this hole by a number of tunnels, and so had a combined effect.

(c) In the remainder of the cylinders a high concentration was maintained for a comparatively short period only.

STUDY AND CONTROL OF THE VECTORS OF RABIES.

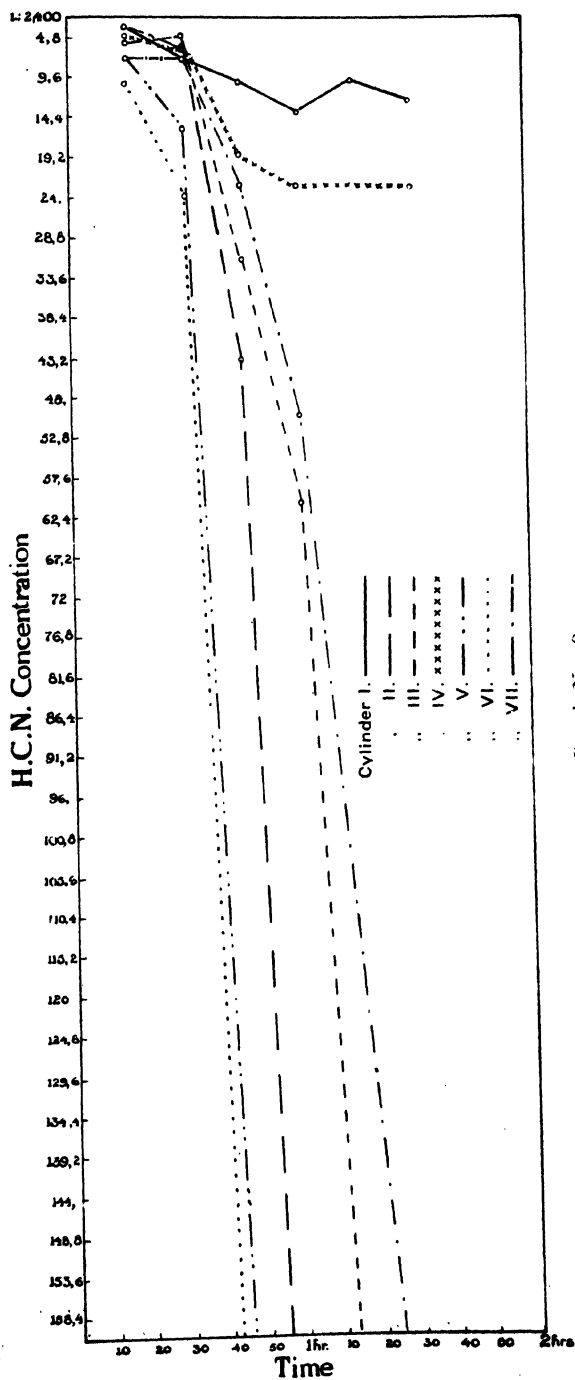


Graph No. 8.

Experiment V

Colony B on Bestersrust

HCN concentration in meercat warrens when using a double-action hand pump



General Discussions.

(1) It is observed in all cases where the hydrogen cyanide concentration was recorded until negative tests or very low concentrations were obtained that the concentration with minor fluctuations remained fairly constant, until a point was reached when it decreased very rapidly. This indicates that the hydrogen cyanide is as rapidly absorbed into the soil as it is given off from the calcium cyanide, when the moisture content ranged from 2.6 to 3.05 per cent.

(2) The length of time the concentration of hydrogen cyanide remained at, or above, a concentration of 1:30-24,000 depends on the amount of calcium cyanide deposited. This is particularly well illustrated in Colony B, Experiment V, where the gassing took place in both instances with compressed air and the hand pump through cylinder I.

(3) Discarding the minor fluctuations in the hydrogen cyanide concentrations as probable experimental errors in judging the intensity of the colouration of the picrate test papers, the major fluctuations in cylinders II and III Experiment IV (Graph 6), II and III Experiment V (Graph 8); II and VI in Experiment I (Graph 3) can only be explained as probably due to air currents in the burrows.

(4) The greatest concentrations in HCN in the burrows were recorded from those openings through which gassing took place, or in openings close to those through which powder was blown into the colony.

(5) Comparison of the efficiency of the gassing by means of compressed air and using a hand-pump:

(a) If the maintenance of the concentration of hydrogen cyanide may be taken as being dependent on the amount of Cyanogas blown into the colonies through the different openings, then less cyanogas is used with compressed air than by using a hand-pump.

(b) By comparing the results obtained on the animals found dead after excavations, it is found that the two methods employed are equally effective, in spite of the fact that very much less powder is used when gassing with compressed air. In both experiments IV and V the carcasses recovered could be accounted for. The only carcasses that could not be accounted for were the one of a *Cynictis* and the one of a *Geosciurus* in Experiment IV. But if it is remembered that two holes were found re-opened after the gassing with compressed air had taken place, and the positions where these carcasses were located, it is thus likely that these animals entered after the gassing with compressed air had taken place.

(6) The only occasion on which a live animal was found after the colony had been dug up was in Experiment II. In this instance the section of the colony in which the *Cynictis* was found was gassed from an opening which connected with the test cylinders II, VI and VII. In the latter two cylinders high concentrations of HCN

were recorded for 2 hours, while in the first a negative test was given. Apart from the fact that the Cynictis had taken refuge in a blind tunnel, his chances of escape were further increased by the very small amount of Hydrogen Cyanide which circulated in that section of the colony. The amount was so small that a negative test was recorded at cylinder III.

(7) From these results obtained in gassing colonies with compressed air and using a hand-pump, it is clear that the effectiveness of gassing meercat burrows with Hydrogen Cyanide does not entirely depend on large amounts of dust being blown into the warrens, so as to maintain high concentrations for long periods, but that it rather depends on a thorough distribution of lethal concentrations of HCN, even for short periods, in the warrens.

Conclusions.

Assuming that the meercats are in their burrows, factors which influence successful gassing can thus be summarised as follows:—

(1) *Distribution of the Dust.*—Of the greatest importance is a thorough distribution of dust in all the warrens of a colony. This can be obtained by using a double-action pump in perfect working order and pumping with continuous forceful strokes, or using a jet of compressed air. A good length of tubing inserted into the burrow as deeply as possible will further assist in blowing the gas to the deeper sections. Before commencing work the operator should satisfy himself that the pump is in good working order, and that none of the parts or the nozzle is choked. The pressure and the cloud of dust should be tested at frequent intervals.

(2) *Quantity of Dust.*—The cloud of dust which is blown out should be first regulated, so that it is easily perceptible and not too thick. It is essential to test this at intervals by one or two strokes of the pump with the nozzle in the open, as the dust sometimes cakes or openings in the dust reservoir may become blocked.

(3) *Quality of Dust.*—Only fresh dust, of good quality, in fine powdery form should be used. The dust should be supplied in the original containers, provided with a press-in lid covered with a screw-on top. The container should always be tightly closed after each filling, since exposure to air deteriorates the powder. Good dust is of a bluish slate colour, and spent dust which is of a brownish colour and is useless, should be discarded. Any dust remaining in the pump after use should always be returned immediately to the container, and the pumps should be cleaned out every morning before operations start.

(4) *Humidity of the Soil.*—A very dry atmosphere retards the liberation of the poisonous gas Hydrogen Cyanide, while on the other hand the gas is readily absorbed into the moisture in the soil. The optimum conditions in the burrows are when the soil can be moulded by hand on applying some pressure. During the rainy season good results will only be obtained if gassing is postponed till the dry spells, when the soil is not saturated with water.

(5) *Looseness or Gas-absorbing Properties of Soil.*—Gas diffuses very easily into loose soil of a porous texture, thus limiting the period for which lethal concentrations are maintained.

(6) *Volume and Intricacy of Tunnel Maze.*—Efficiency in gassing a colony does not so much depend on the size of the colony as on the intricacy of the tunnel maze. The airflow usually takes the line of least resistance, with the result that the gas does not circulate in side tunnels and by-passes.

(7) *Presence of Blind Ends or Air Locks in the Tunnel System.*—In nearly every instance where live meercats were found after gassing, they were recovered from blind-ends or where air-locks existed. On no account should holes be closed before dust has emerged from them.

(8) *Presence of Obstruction in Tunnel.*—Very frequently an animal or caved-in earth forms an obstruction to the passage of the gas. The latter obstruction frequently happens in winter before rains have fallen, and the burrows have not been cleaned out by the inhabitants. Gassing should be commenced at those holes which show fresh activities and recent occupation or excavations.

(b) *Carbon Monoxide.*

The next gas tested was Carbon Monoxide. An easy, but not the least economical way to obtain the gas, or a mixture of it and Carbon Dioxide, is from the exhaust pipe of a motor-car. A long hose-pipe was connected to the exhaust-pipe, and the free end inserted into the openings of the burrows, while the engine was running at a speed corresponding to 10-15 miles per hour in top gear. As a test to see if the gas emerged from an opening, an ordinary lighted safety match was used. The lighted match was lowered as far down the opening as the hand could reach. If the light was extinguished the hole was closed. Repeated check tests were made at the same hole. The hose-pipe, as in the case of dusting with a pump, was inserted into successive openings until all the openings had been closed.

The first test was performed at Beestekraal, 2.2.38. Two *Cynictis* were seen to enter a colony, which was then gassed. Five days later the openings were still closed; one can assume, therefore, that they were killed.

The second test was on a colony at Bestersrust on 5.5.38 into which two *Cynictis* were seen to enter. The gassing lasted 25 minutes. On partial excavation 1 dead *Cynictis* and 1 dead *Geosciurus* were recovered, from which one can conclude that the gas is effective. It has since come to my notice that there is a small portable CO generator on the market. If it should prove efficient there is little doubt that the cost of gassing would, therefore be greatly reduced.

(c) *Sulphurous Gases.*

Various makes of gas-cartridges or fumigators are found on the market, guaranteed to be effective in eradicating small burrowing animals.

On account of their economy, only requiring one man to operate, these fumigators were tested on the Vryburg Commonage during November, 1938.

The fumigators used are designed to generate on burning, Hydrogen Sulphide, Carbon Monoxide, Carbon Disulphide and small quantities of Sulphur Dioxide. The lethal gases are only generated if the cartridges are burnt under the proper conditions, i.e., in a restricted space. If burned in the open the gases formed are Sulphur Dioxide and Carbon Dioxide. Each cartridge gives off one cubic foot of gas. The lethal properties of the gases in the burrow will persist for ten minutes. If the soil is damp, Hydrogen Sulphide will dissolve in the soil moisture.

The fumigators were used according to directions and under ideal conditions, no rain having fallen since the previous summer. The holes that were not to be charged were closed according to directions, and from one to two cartridges were ignited and inserted into the other holes, which were immediately closed.

On the day following the first test, it was found that all the colonies had been reopened. Consequently, in the next colony as many as five cartridges were inserted in one hole, and in many instances cartridges were inserted in every hole of the entire colony. Even this gave disappointing results. It was then decided to establish definitely the effect of these gases on two colonies. One of a very simple construction, and the other of a more complicated structure, were selected. (See sketch 2.)

As a test for the sulphuretted Hydrogen, Lead Acetate papers freshly prepared were used, and employed in the same way as the picrate test for Hydrogen Cyanide.

It was noticed that the fumes, liberated from the ignited cartridge on insertion in the hole, were drawn in, and advantage was taken of this as the cartridges were too big to be inserted through the stoppered openings in the test cylinders. The ignited cartridges were inserted and the cylinders were placed in position as quickly as possible. The actual times, when the cartridges were inserted, were noted.

Experiment 1.

This was conducted on a colony of simple structure, consisting of five openings only, connected by straight tunnels without branches. One cartridge was inserted into each hole. Lead Acetate tests were not conducted. See Sketch No. 2.

Results.—On excavation of the colony two dead squirrels were found at the places indicated on the sketch. In all five live suricates were found at the places indicated. At hole No. III one suricate escaped and ran away. The other two in the same burrow were prevented just in time from escaping, by one of the labourers placing his foot on the opening. The hole was closed and a cartridge was inserted at the point indicated on the sketch. The tunnel was then

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about three feet long. After three minutes of interruption the excavations were continued, and both suricates were found dead. The other two suricates were killed in the same way.

Experiment II.

A fair sized colony was selected for this experiment. Two *Cynictis* were seen to enter it, and later the suricate that escaped from the colony above also entered into one of the burrows. In some of the openings two cartridges were inserted while in others only a single cartridge was inserted. The Roman numerals indicate the identification numbers of the test-cylinders. The other holes were closed up before the cartridges were inserted. Lead-Acetate-tests were performed at fifteen minute intervals.

Results.

The details of the Lead Acetate test are recorded in the Table 5.

TABLE 5.

Large Colony. Experiment II. Vryburg 16.11.38.

Lead Acetate Test; Gas Cartridges, Liberating Hydrogen-Sulphide and other Sulphurous Gasses.

Time of Test, at 15 Minutes Interval.	Cylinder No. I, Loaded.	Cylinder No. II, Loaded.	Cylinder No. III, Loaded.	Cylinder No. IV, Unloaded.
10 a.m.....	Instantaneous..	Instantaneous..	Instantaneous..	Some delay.
10.15 a.m.....	Instantaneous..	Instantaneous..	Instantaneous..	Negative.
10.30 a.m.....	Slight delay....	Slight delay....	Instantaneous..	Negative.
10.45 a.m.....	Slight delay....	Slight delay....	Instantaneous..	Negative.
11 a.m.....	Delayed.....	Weak.....	Instantaneous..	Negative.
11.15 a.m.....	Weak.....	Weak.....	Instantaneous..	Negative.
11.30 a.m.....	Weak.....	Weak.....	Delayed.....	Negative.

On excavation both the *Cynictis* were found alive, as well as the *Suricata*. One *Cynictis* was killed with a gas cartridge when only 24in. of tunnel was left.

Experiment III.

An experiment with fumigators was repeated on a "Trassiebos" colony on the Hoopstad commonage a week later. Four *Cynictis* were seen to enter the colony. Out of the ten openings, seven were charged. On excavations two adult *Cynictis* escaped, while two young ones about six weeks old were found dead at a place 24 inches from where two cartridges were inserted.

Conclusions.

The fumigators, that were used, are ineffective on meercats under ordinary circumstances, and effective only in short tunnels, in which an exceedingly high concentration of gases can be obtained.

The slow rate of diffusion, which is dependent solely on the density of the heavy gases and not assisted by any air currents in the tunnels, coupled with the quick rate of absorption of the lethal gases into the soil, renders the use of such fumigators impracticable.

On account of disappointing results, the use of gas-cartridges liberating lethal gases cannot be recommended for the eradication of meercats.

(d) *Heavy Gases.*

(1) It was considered that if heavy poisonous gases could be liberated in the warrens, they would gravitate to the deeper sections and so reach the animals, which could otherwise not come in contact with the gases used in the previous experiments.

Carbon Bisulphide gas was thought to be suitable. Before the experiment was begun, the M.L.C. was established. This was done the following way. A *Geosciurus* was introduced into the lethal box described above. Five c.c. of CS_2 were poured on cotton wool and introduced into the box.

Results.—After six minutes the animal showed no effects beyond coughing during the first minute. A further 10 c.c. were introduced. Two minutes afterwards the animal scratched its nose and fell over. The respirations became shallow and slow, and eventually it died 22½ minutes after introduction of the further 10 c.c. of Carbon Bisulphide.

As a result of the large amount of Carbon Bisulphide which had to be used, and which proved fatal, only after 22 minutes, the experiment was abandoned.

Heavy war gases like Chloropicrin and mustard gas, which are five times as heavy as air, were also considered, but not being procurable locally they could not be tried. On account of their expense and danger in handling, it is doubtful whether their use could even become a practical proposition.

(2) *Granulated Calcium Cyanide.*—Hydrogen Cyanide is liberated very slowly from granulated Calcium Cyanide. Advantage was taken of this to create, in the opening of the warrens, chambers in which the air was charged with Hydrogen Cyanide, the idea being that such chambers would form a trap, and so gas the animal entering it.

Colony 162 at Beestekraal was selected for this experiment. Two *Cynictis* were seen to enter the colony. The lethal chambers were constructed as follows:—

The warrens were closed at arm's length on the inside with earth. A heaped-up teaspoonful of granulated Calcium Cyanide was deposited in a heap, and the opening was finally closed with earth.

Another unnumbered colony was treated in the same way.

The following morning on inspection one hole was found open, through which the meercats evidently had escaped. The other holes were opened by hand to find the chambers intact. In the other colony all the chambers were intact.

Further trials were not carried out.

2. TRAPPING.

All three species of animals are very easily trapped with ordinary three-inch gin-traps. (Illustration 10.)

Setting of Traps.—The methods which gave the most success are shortly as follows: After the hole at which the trap is to be set has been selected, sand is pushed into it until about a third of it is filled up, care being taken to fill only so much as will allow free action of the jaws of the trap, and avoid contact with the roof or the sides of the hole. This partial filling of the opening prevents the animal from avoiding the trap and compels it to crouch when entering, thus putting more weight on the catch. The trap is set in position and the catch covered with soft paper to prevent the sand, with which the whole trap is covered up, from getting under the catch and so preventing it from being released. The chain is staked to the side of the entrance. The sand is then smoothed over with the hand, and brushed lightly with a twig to obscure signs of human interference.

Selecting of the Burrows at which to set Traps.

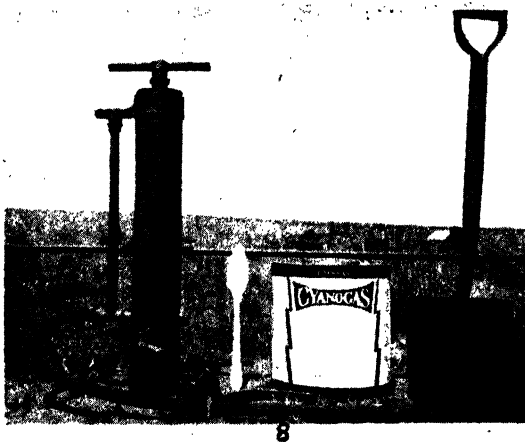
As will be described later, traps were set at those colonies which became reoccupied after gassing, or in which gassing had failed to kill all the inhabitants. In these cases traps were set at all the burrows that had been reopened.

The system of trapping and its effectiveness are described more fully later.

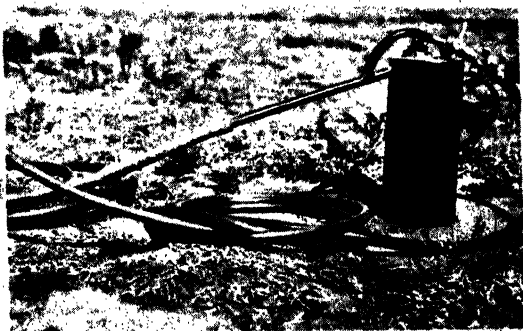
By way of demonstration, experiments to ascertain to what extent the inhabitants of a colony can be exterminated by trapping, were carried out at Sannahspost on 28th February and 2nd March, 1939. Traps were set at different colonies in the burrows, which were in use. The other openings were closed up with earth and trampled down. In the first case 40 traps were set at seven colonies and 35 meercats were trapped, and in the second 31 traps were set and 24 meercats trapped. On both occasions all the inhabitants were caught, since no further holes were opened up.

3. EXPLOSIVES AS A MEANS OF DESTRUCTION.

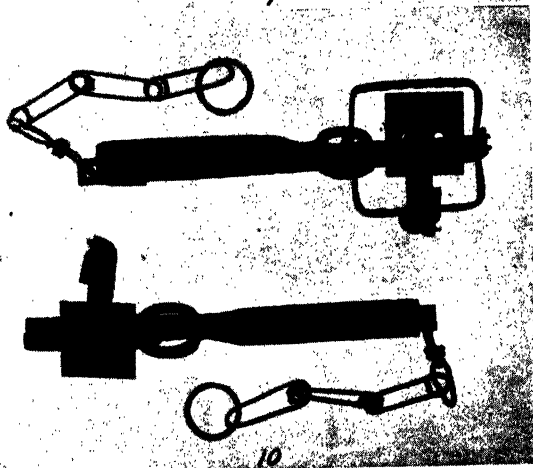
When it was decided to undertake experiments to investigate the effect of explosives, African Explosives and Industries Ltd. of S.A. was approached with a view to obtaining some information regarding the use of explosives to the best advantage on meercat warrens. The Company kindly placed the service of one of its experts, Mr. E. A. Hendry of the Explosives Service Station, at our disposal.



8



9



10

Illustration 8.—(Top.) Gassing equipment, consisting of Schoeman double-action pump, spanner for opening the dust chamber, and a spoon for filling it; a supply of (yanogas and a spade for closing the holes where the gas escapes.

Illustration 9.—(Middle.) Thomas insufflator.

Illustration 10.—(Below.) 3 inch Metal gintraps, used for trapping meercats.

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This gentleman personally supervised all the trials conducted, and failure cannot, therefore, be attributed to amateurish and inefficient use of explosives.

(a) In loading up a colony, charges varying from $\frac{1}{2}$ to 2 lb. of explosives were used. The cartridges were pushed as far down each of the burrows as possible, before filling up the holes behind with sand. The electric detonators, with which the charge was to be exploded, were connected up in series and fired with an 80 shot electric-exploder through 100 yards of cable. A certain amount of difficulty was experienced in loading as the majority of the burrows twisted considerably, and it was only possible to push the charges down for about 2-3 feet, although in certain cases the charges could be pushed down three or four feet with a stick.

In all cases the holes which were not charged were filled in with soil.

The time of charging up, including making up of primers, varied from half an hour for small "Trassiebos" colonies to two hours for a large underground colony.

Both 40 per cent. dynamite and 40 per cent. Ammon. Gelignite were used.

Altogether 11 colonies were blasted for which 150 lb. of explosives and 151 electric detonators were required.

After the explosions had taken place, the surface effects were noted before the colony was completely dug up to examine the effect of the blasting.

The results of the trials are summarised in Table 6.

Remarks.

In one instance three holes were put down with a jumper in a "Trassiebos" colony, but owing to the dry, sandy nature of the soil, on withdrawal of the jumper the holes became partly filled with sand. An attempt was also made to chamber one of the holes, but on one $\frac{3}{4}$ in. by 4 in. cartridge being fired inside it became completely filled up with sand.

It was suggested that holes should be put down in underground colonies by means of jumpers, to increase the blasting effect, but even if the difficulty of sand filling the holes was overcome, this method was regarded as impracticable, as a very large number of holes would be required to cover a colony and, even then, there would be no certainty of the explosion reaching meercats in long blind tunnels.

From the table it will be seen, that in spite of the large amount of explosives used in some colonies, the results were very disappointing. As many meercats survived the explosion as were killed. Even in cases where half the sand-mound was blown away, live meercats were found.

No. of Colony.	Type of Colony.	REMARKS.
1 (1).....	Underground...	meercats were found in one blind tunnel 3 feet underground and 15 feet away from the surface burrows, and 1 female and young were found in another blind tunnel also 3 feet underground and about 30 feet away from the central colony.
2 (73).....	Underground...	again what appeared to be long blind tunnels were located and digging was stopped.
3 (60).....	Underground...	digging was not completed. It is surmised that one meercat escaped at night.
4 (45).....	"Trassiebos"...	After turning after blasting one meercat was observed to crawl and stagger away.
5 (41).....	"Trassiebos"...	It is not known how many meercats were in this Colony. It is possible that one escaped alive.
6 (46).....	"Trassiebos"...	No definite result. An attempt to put down jumperholes was made, but was unsuccessful on account of the sandy nature of the soil.
7 (50).....	"Trassiebos"...	The mounds of the mound were not affected by the blast.
8 (14).....	"Trassiebos"...	No evidence was found of any meercats having escaped between the time of blasting and the time of digging up.
9 (127).....	Underground...	The total number of meercats in the colony at the time of the blast is not known. The deepest crater formed was 3 feet deep.
10 (123).....	Underground...	The outer portions of the colony away from the charges were left intact.
11 Trompsburg	Underground...	One meercat was shattered. The meercat found crawled out after the blasting.

The following reasons for the disappointing results were deduced.

In underground colonies, charges cannot be pushed down to any depth owing to the winding of the tunnels, and consequently only local shattering results.

The explosion does not appear effectively to penetrate the lower levels of the burrows, and it would appear that meercats in the ends of blind-tunnels, about 3 feet underground and well away from the surface burrows, are practically immune from the effects of the blast.

Other factors tending to reduce the efficacy of the blasts are, that charges cannot be properly stamped in the burrows owing to the size of the latter, and that sand in the burrows has a damping effect on the explosion. In rocky ground where concussion should be greater, it was found that quite large cavities exist under the boulders, and also that burrows are more widely spaced, tending to reduce the effect of the blast.

In "Trassiebos" colonies a good deal of the sand is scraped out, this, combined with the fact that the mounds are composed of sand, would have the effect of reducing the concussion to a very great degree. It was thought that, in those colonies where meercats were found dead, they had been partly stunned and then suffocated by the fallen sand and explosive fumes.

Conclusion.

Owing to the large amount of explosives necessary to blast a colony and the time required to charge up, coupled with expense and poor results, it was concluded that the use of explosives for the destruction of meercats and their burrows is not a practical proposition.

4. POISONING WITH BAIT.

One of the commonest methods of eradicating vermin is by means of poisoned bait.

On preliminary trials it was found that the yellow mongoose would devour the fresh carcasses of birds, which were shot and placed near their warrens. Experiments were then carried out to test the efficacy of Strychnine sulphate.

Experiment 1.

$\frac{1}{8}$ Grain of strychnine sulphate was fed in a piece of meat to *Cynictis* (juvenile) at 2.48 p.m. At 6.40 p.m. the animal showed signs of inco-ordination of movements, and died during the night.

Experiment 2.

$\frac{1}{4}$ Grain of strychnine sulphate dissolved in 5 c.c. of water was injected subcutaneously into the left thigh of a *Geosciurus*. The animal died after two minutes, showing violent convulsions and arching of the back.

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Remarks.

Poisoning the yellow mongoose on a large scale is not recommended, owing to the danger of large stock getting access to the bait, especially in pica areas.

The danger to native piccanins is even more real, as piccanins may pick up and eat the bait if birds are used.

When an owner wishes to kill off a few chicken-thieving mongooses, poisoning on a small scale may be practicable; but the method is obviously involved, uncertain, and dangerous for general use.

B. Attempts at Large Scale Eradication of Meercats.

The best method of destroying the yellow mongoose having been determined, experiments were planned to investigate the possibilities and the technique of exterminating it in large areas, and to observe the extent to which migration back into the areas, of the yellow mongoose would take place

For this purpose, two adjoining farms, Beestekraal and Middagson in the Hoopstad District, were chosen, on account of (a) being infected with rabies (an outbreak in a dog having occurred there on 27th March, 1937) and (b) their situation in typical mongoose country.

GENERAL DESCRIPTION OF THE FARMS BEESTEKRAAL AND MIDDAGSÓN.

The two farms mentioned are rectangular in shape, about $1\frac{1}{4}$ miles wide by 4 miles long, bordering the Vet River on the south.

They stretch northward from the Vet River, on which they have about three miles frontage, into a sand-hillock for approximately three miles. Both farms are ring-fenced, and subdivided into several fenced camps. The farms Beestekraal and Middagson are about 1,400 and 1,000 morgen respectively in extent. About 400 head of cattle, including a few horses, had been kept at Beestekraal for the previous three years, and there were 100 head of cattle at Middagson.

Both farms can be divided topographically into two distinct parts, viz. a low lying area adjoining the Vet River, and the higher part in the sandbult-hillock. The Bloemhof-Hoopstad main road running from East to West, incidentally corresponds to a line separating these two parts.

That part of the low-lying area immediately adjoining the Vet River is flooded in the rainy season, when the river overflows its banks. The water disappears soon after the river has subsided. The soil, which becomes very hard when dry, is a black clay. This area is marked by tall trees, mostly *Acacia karroo*. From the low land the ground rises very gradually to the main road, where it merges into the sand-hillock in a sharp rise. The soil here consists of clay in the deeper layers and sand in the superficial layers. The vegetation

is sparse, but characterized by "Trassiebos" mounds (*Acacia stolonifera*) which average 10-20 yards in diameter and are spaced from 20 to 100 yards, with an occasional *Acacia karroo* between.

The sand-hillock portion starts with a sharp rise from the main road, and rises steadily until the northern boundary is reached. The soil is of a very loose sandy nature and easily blown away when dry. The vegetation consists of various species of tall grasses and Camel-thorn trees (*Acacia giraffae*) which forms the climax stage.

The altitude of the farms is 4,100 feet.

Observations Made.

The two farms together were treated as one area, and, to facilitate plotting as well as systematic covering of the ground, was paced off and marked into squares of approximately 400 yards a side.

After the outer boundaries had been traced on squared paper, the flagged squares were also marked in.

Each flagged area was carefully searched for meercat colonies, which were marked and numbered for identification purposes, and the site recorded with a corresponding number on the sketch-plan. Detailed remarks, as to the size of the colony, whether there were signs of inhabitants, were made. The latter observations were made as meercats, when disturbed, usually rushed back into their colonies to take refuge.

It was generally possible to determine the species of meercat inhabiting a colony by the tracks, and the fact that *Cynictis* usually selects a spot near its colony to the leeward of some bush or stone, or in a hollow to defaecate, and fresh faeces in such a spot near the colony indicates the presence of *Cynictis*.

During the excursions to locate the colonies, notes were made on the nature of the soil in which the colonies were located, the habits of the meercats, the occurrence of food. A general survey of the flora and fauna was also done at the same time. The diet of the different species of animals and birds found in the area was established by examination of the stomach contents of those shot or trapped.

It was realised at the outset that, in order to exterminate the yellow mongoose and the suricate, those colonies occupied by the squirrels had to be gassed as well, as the latter live in very close association and often congregate in the same colonies. It was also obvious that, unless all colonies were closed, one would not be able to judge whether all the mongooses and suricates had been destroyed. In any case the squirrel is regarded as vermin on account of the destruction to mealie fields, and one thus felt quite justified in including it in the campaign against the other two species.

As soon as the task of locating and flagging off the colonies was completed, which took about a month of fairly continuous work, gassing operations were started.

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The technique of gassing a colony with Calcium Cyanide dust has already been described.

The routine adopted at the commencement of the operations was shortly as follows: Early in the morning before the meercats had dispersed, natives were sent out to watch the inhabited colonies in a given area. They were instructed to chase back into their warrens any meercats seen to emerge, and then to keep guard pending the arrival of the gang armed with the gassing apparatus.

All the natives including those of the advance party carried spades with which to close all uninhabited colonies, and to fill in any odd holes they came across in the veld.

This was continued until about 11 a.m., as it was found that after that time and until late in the afternoon very few meercats were seen. The operations were resumed at about 4 p.m., and continued until dusk.

Periodic inspections were made of the colonies that were gassed, and any that were found reopened were regassed.

It was soon found that several colonies had to be gassed repeatedly; e.g. Colony 61, inhabited by *Geosciurus*, was gassed five times without any conclusive results. It was found in many instances that only a single warren had been reopened and in order to save dusting powder, time, and labour, gin-traps were set at these burrows.

On account of this experience the routine was then changed somewhat. Instead of gassing reopened colonies, traps were set at the warrens reopened, until the animals responsible had been trapped.

Two natives were then detailed to make periodic inspections of the areas treated, and at any warrens found open they had to set traps. If a trap remained unsprung for two days, it was removed and the hole closed.

On or about the 5th February, 1939, the routine was again changed. Instead of having advance parties, all the natives with the gassing outfit set out together, and walked in extended rank formation spaced at from 50 to 150 yards according to the density of the grass. This procedure proved very effective for rounding up the meercats, and so chasing them into their warrens, which were then gassed. This procedure had the further advantage in that the work could proceed uninterruptedly. In the area so traversed all colonies were fumigated, unless they were obviously not inhabited, when they were merely closed.

A complete record of each colony was kept, giving the dates of subsequent visits and regassing, whether any warrens were found reopened, the number of traps set, and the results.

The following is a brief summary of the histories of the colonies found and treated at Beestekraal and at Middagson:

(a) In all, 150 colonies were located.

(b) 35 colonies were unoccupied; but 6 became occupied later, after the first summer rains.

- (c) 65 colonies of those gassed remained closed until the 2nd of March, 1938, when the operations were completed.
- (d) 50 colonies were reopened by meercats subsequent to the initial gassing. Of these, in 13 instances meercats were actually seen to inhabit them again, and eleven of these were regassed. In the other 39 the inmates were not seen, but numerous spoors were seen and seven animals trapped.
- (e) 29 colonies were not revisited until some time afterwards, when they were found to have been reopened.
- (f) 21 colonies were still closed on a re-inspection some days after the gassing, but were found reopened at a subsequent inspection.

Remarks.

(a) In all, some 150 colonies were found on the two farms. In some instances two to four colonies existed very close to one another, especially in the "Trassiebos" area. These were collectively given one number, but were identified separately with alphabetical letters, e.g. Col. 68: a, b and c.

(b) 35 colonies were marked as uninhabited or abandoned colonies, which were not gassed but closed in: of these, 6 were later found to be inhabited, viz., Nos. 32, 66, 81, 98, 150 and 152. No. 32 was found inhabited on 3.1.38. It was then gassed and was still closed on 5.2.38. On 9th February some holes were found reopened and traps were set, with the result that 2 squirrels were trapped. The holes were then closed again, and were still closed on the 2nd of the following month.

The history of two of these colonies is given in detail, to indicate to what extent they became occupied and how they were treated.

Colony 98.—The colony appeared uninhabited on 11th January, 1938. On the 25th one warren was found reopened, and was closed again as no signs of its being inhabited were seen. On 1st February several warrens showed fresh excavations. The colony was gassed and the holes were closed. On the 14th it was still closed, but five warrens were found to have been reopened on the 21st. The colony was again gassed and remained closed until the 28th. On 1st March two warrens were found reopened and traps were set, but again removed after two days as they were not sprung.

Colony 150.—On 28.1.38 the colony appeared as if it had been vacated and was visited repeatedly until 22nd February, when seven warrens were found open. Numerous fresh spoors were present. The colony was gassed, and remained closed until 2nd March.

The other two colonies, 66 and 152, remained closed when they had been gassed.

(c) Out of the total number of colonies found inhabited and gassed, 65 remained closed after only one gassing. In 38 instances of these, either one or more were yellow mongoose or squirrels, and in three instances both species of animals were seen to enter immediately prior to gassing.

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(d) Of the total number of colonies gassed 50 were reopened by meercats or other animals, subsequent to the gassing. Of this number 21 colonies were closed on reinspection at different times, while 29 colonies which were not visited for some time were found open at the subsequent inspection.

In 13 cases of the 50 which were found reopened, meercats were actually seen to enter and inhabit these, and eleven of these remained closed on regassing, while the other two had to be regassed several times. In the other colonies traps were set, and in seven instances the new inhabitants were trapped.

In order to indicate the difficulty experienced in some instances in destroying the inhabitants of the colonies, and to show how they became reoccupied, the history in detail of a few colonies is given.

Colony 63.—On 30th December, 1937, two squirrels entered the colony, whereupon it was immediately gassed. On 3rd January it was still closed. On the morning of the 11th January several warrens were found open, and two squirrels and two mongooses were trapped, whereafter the colony remained closed until 28th February.

Colony 87.—On the 11th January, three *Cynictis* were seen to enter whereupon the colony was gassed. It remained closed until the 14th, when two warrens were found to have been reopened. The colony was regassed after the other holes had been re-opened to allow the free circulation of gas.

On 3rd March one warren was found re-opened, and a trap was set but remained unsprung for two days.

Colony 101.—On 9th November, four *Cynictis* and five *Geosciurus* entered the burrows. On 4th December one *Cynictis* was trapped. On 4th January four *Geosciurus* and three *Cynictis* were seen to enter the colony, whereupon it was gassed. On the 12th there were signs of its being inhabited again, and one *Cynictis* was trapped. The colony then remained closed till 28th February.

Colony 110.—On 10th January as fresh tracks and faeces were found, the colony was gassed at 12 noon. On the 27th five warrens were found open showing fresh excavations. The colony was again dusted.

On 21st February two warrens were opened and fresh tracks were found. The colony was regassed. On the 24th it was still closed, but one warren was found reopened on the following day, when a trap was set and a *Cynictis* trapped. On 1st March it was still closed.

Colony 131.—On 12th January a *Geosciurus* entered the colony which was then gassed. On the 21st it was still closed. On the 7th a *Cynictis* and a *Geosciurus* entered, and two traps were set. A *Geosciurus* was trapped on the 10th, and a *Cynictis* on the 15th. On 21st February a *Myonax* was trapped in the same colony. On the 23rd another *Cynictis* was trapped. The colony then remained closed.

Colony 140.—On 12th January 4 *Suricates*, 5 *Geosciurus* and 4 *Cynictis* emerged from the colony but were chased back, whereupon the colony was gassed. On the 28th five warrens were found to have been reopened, fresh tracks and faeces being present.

On the 28th the colony was regassed. On 9th February six warrens were found reopened, whereupon the colony received a further gassing. It then remained closed until the 23rd when 8 warrens were once more found reopened, and two *Cynictis* were trapped. It then remained closed until 2nd March.

PHILIP-HOOPSTAD DISTRICT.

On 10th April, 1938, experiments were arranged on the farm Philip, firstly to follow up the gassing of colonies with systematic trapping of the meercats that had escaped gassing, and of those which had filtered into the ground already treated and which were responsible for reopening colonies treated; and secondly to repeat some of the hydrogen cyanide concentration experiments in colonies.

General Description.

The farm Philip is situated seven miles to the south of Wesselsbron at an altitude of 4,350 ft., and is 1,400 morgen in extent. The average annual rainfall is 15·20 in.

The larger part of the farm consists of a sand-hillock with numerous small pan-like depressions. The sand-hillock slopes down to a large pan, typical of that part of the country. The soil on the hillock is of a deep sandy nature, in which mealies are extensively cultivated. The whole farm is devoid of trees, except for a small patch of young *Acacia karroo* near the northern boundary.

The sandy soil gradually changes on the slopes near the pan into a brown turf, with lime subsoil. The pan contains water during the rainy season, but soon dries up leaving a level and caked bed.

Vegetation.

The vegetation consists mainly of a mixed variety of grasses, with *Arastida*, *Themeda* and *Chloris* spp., *Cynodon* and *Aristida* being dominant on uncultivated land. The "stand" of mealies in the different fields was good owing to abundant rains.

Fauna.

The majority of the meercat colonies were situated along the slopes of the big pan, and mostly inhabited by *Geosciurus*, although *Cynictis* was fairly prevalent as well. The owner informed us that a large family of *Suricates* periodically inhabited various colonies along the pan.

The colonies on the hillock were usually close to the mealie-fields and along the slopes of the pan-like depressions. The former were predominantly occupied by *Geosciurus*, while *Cynictis*, which favoured the hillock, occupied the colonies along the pan-like depressions.

One was struck by the scarcity of Korhaan and other ground birds. Very few springhare (*Pedetes caffer*) inhabited colonies were seen. The few that did exist were inhabited by individual animals only. This was explained by the owner, who stated that a Springhare club existed in the area aiming at total eradication, by systematic hunts, etc., as the animals cause considerable damage to the mealie crops.

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Hodotermes were plentiful and very active. An outbreak of rabies occurred on this farm in an ox on 7th November, 1937, and, on 23rd May while the experiments were in progress, a rabid *Cynictis* was found in the same camp, where the ox became ill.

Procedure.

As the object of the experiment on Philip was to follow up the gassing with systematic trapping and so to exterminate the meercats on the farm, it was therefore arranged that a definite area be gassed each day. The day following the gassing of a particular area, it was covered again to set traps at any warrens that had been reopened. This was followed by periodic inspections at short intervals to set fresh traps, if necessary. The trapping was continued until no further holes were reopened.

For the purpose of working out a daily programme a survey of the farm was made, and the colonies located were roughly marked on a sketch-map. It was then very easy to divide the whole of the farm into areas, special consideration being given to localities where the colonies were more closely situated together, so as uninterruptedly to gas such an area in one day in order to minimize the chances of reinfestation from neighbouring colonies still untreated.

Results and Observations.

(a) In all 92 colonies were located on the farm, of which 13 were uninhabited and not gassed, but only closed.

(b) Of the 79 colonies gassed, 45 remained closed until 26th May, when the operations were completed, i.e. when it was considered that all the meercats on the farm had been exterminated. Thirty-four of the colonies were re-opened subsequent to the gassing.

(c) Eleven colonies were found re-opened once only.

(d) Seven colonies were found re-opened twice.

(e) Eight colonies were found re-opened three times or more.

(f) In 20 instances where colonies had been found re-opened, no meercats were trapped.

(g) Only one colony was found re-opened on the day following gassing.

(h) In only two instances were colonies found re-opened on the 2nd day following the gassing.

(i) In two out of the thirteen colonies regarded as unoccupied at the time of the general survey of the farm, warrens were re-opened. In one case a *Cynictis* was trapped, whereas the trap remained unsprung in each of the others.

(j) On 25th and 26th May, when the final inspection was made, only nine colonies showed meercat activity. In three cases the traps had not been sprung, while in four instances meercats had been trapped, viz. three *Geosciurus*, one *Cynictis* and one *Suricata*. In the remaining two cases no further observations could be made, owing to our departure from the farm.

(k) In twelve cases the colony was dug open by meercats between the 4th and 10th day after gassing.

Subsequent Inspections at Beestekraal, Middagson, and Philip.

In order to determine to what extent meercat migration will take place into areas in which meercats have been exterminated, subsequent visits were paid to the farms Beestekraal, Middagson, and Philip.

Beestekraal and Middagson.

Visits on the 7th, 8th and 13th April, 1938, i.e. 33 days after the operations had been suspended.—Out of 110 colonies visited, mainly on the area north of the Bloemhof-Hoopstad main road, 31 colonies were found re-opened, of which 18 only showed signs of being inhabited. The other 13 were abandoned. Colonies 113 and 110 each had 9 warrens re-opened; numerous fresh spoor were seen and the usual heap of fresh faeces of *Cynictis* was present. In colonies 63 and 68, eight and three warrens respectively, were re-opened and a *Cynictis* and a *Geosciurus* escaped into them.

Visits on 24th to 26th November, 1938, i.e. 10 Months afterwards.—Some 105 colonies were visited. While 32 colonies showed definite signs of being inhabited, 88 were still closed, or partially opened but abandoned. The extent to which the colonies were re-opened varied a great deal. In the smaller ones all the holes were found re-opened, whereas in the bigger ones only some of the holes on the periphery had been re-opened and occupied. It was found that the colonies near the boundaries of the farms showed more meercat activities than those near the centre of the farms, although some of the colonies towards the centre of the farms were also well attended.

The only area into which meercats had definitely not migrated was that in the vicinity of the farmyard.

An attempt was made to take a census of the meercats, but owing to the tall grass this had to be abandoned. Only twenty mongooses and ten suricates were seen. From the activities manifest at the various colonies, it was estimated that the reoccupation of the colonies was from one to three per colony, so that the total number, at a conservative estimate, was from fifty to sixty meercats on the farm.

Visits on 8th June, 1939.—An excursion was made to the farm Beestekraal only some fifteen months after the initial operations. On the sand-hillock all the colonies that were encountered had been re-opened, and showed signs of long habitation, viz. excavations and faeces observed. In the majority of cases the fresh excavations were on the periphery of the colonies, the rest of the warrens still being closed. The area in the vicinity of the farmyard showed very little activity. In the area immediately to the south of the Bloemhof-Hoopstad road, all the "Trassiebos" mounds had been excavated and were inhabited. Except for the small area near the farmyard, it was considered that meercat activity over the whole area had reached the same stage as before the trial eradication at the beginning of the previous year.

Philip.

Visit on 29th June, 1938, i.e., 34 days after the meercats on the farm had been eradicated.—Some 44 colonies were visited, of which 29 showed signs of being occupied by meercats. Fresh spoor, and/or faeces were found at each of the colonies. Several colonies had been completely re-opened; e.g., No. 105 had 24 warrens re-opened and was occupied by squirrels; No. 139 had 12 warrens re-opened. Thirteen colonies had been re-opened but no spoors or faeces were seen.

Visit on 27-29 November, 1938.—On this date 80 colonies were inspected with the following results: 21 colonies were reinhabited; five mongooses and three squirrels were seen. As in the cases of Beestekraal and Middagson, the number of warrens re-opened varied from one to ten per colony. Colony 66 had ten warrens re-opened.

Visit on 9th June, 1939.—The inspection of the colonies was confined to a portion of the hillock along the main road, the vicinity of the pan and the eastern portion of the farm. All the colonies encountered had been re-opened and showed signs of having been inhabited for a long time. The colonies in the hillock, which were inhabited by *Cynictis* had only a few warrens on the periphery re-opened, while those inhabited by *Geosciurus* had all the warrens re-opened. The distribution of the meercats was more or less even over the area visited.

Remarks on the Observations Made and Results Obtained at the Farms Beestekraal, Middagson, and Philip.

(1) In both the areas about half of the number of colonies gassed was found re-opened subsequently to being gassed. The re-opening of the colonies was ascribed to meercats that—

- (a) had escaped the gas in the colonies and had dug themselves out;
- (b) were away at the time of gassing, and had returned to dig themselves in;
- (c) wander from colony to colony, probably looking for mates. They usually open a few holes, but not being attracted go away again.
- (d) come from elsewhere, migrating into new hunting ground, where they find suitable shelter by merely opening up and cleaning out existing colonies.

These animals were all trapped.

(2) If an analysis is made of the results obtained at Philip, where the gassing of the colonies was followed up by repeated inspections, it is seen that some colonies become reoccupied at different intervals. In some instances this occurred as many as three times, e.g., colonies Nos. 6, 62, 115, etc.

The new inhabitants of a colony do not necessarily consist of the same species as the original ones, but they may consist of a different species of meercat, or of all three species.

Considering only those colonies where the new inhabitants were trapped, the analysis shows that nine colonies became reoccupied between the 6th and 10th days, six between the 11th and 15th, six between the 16th and 20th, three between the 21st and 25th, four between the 26th and 30th, and three after the 30th day following the gassing.

Migration of meercats, therefore, takes place to a greater extent soon after an area has been treated, but as the number of meercats available in the neighbourhood is being steadily reduced by gassing and trapping, the rate of migration becomes reduced, until finally a stage is reached when the infiltration becomes negligible.

After the extermination of meercats in any locality by the methods outlined above, it should be a comparatively easy matter if so desired to maintain effective control over such area with very small expenditure of time and money, by making frequent periodic inspections and setting traps at any warrens, that have been re-opened.

Especially would this be the case with *Cynictis*, the most important carrier of the disease. This animal, unlike *Geosciurus*, when occupying a new colony, only opens and uses a few warrens on the periphery.

(3) On the other hand, if no check is placed on the migration of meercats to such a farm, it soon becomes reinfested with meercats, as is clearly shown by the observations made on the subsequent visits to Beestekraal, Middagson and Philip. In both instances after an interval of 33 days on the first-mentioned farms, 18 out of 110 colonies visited, and in the latter 29 out of 44, were re-occupied by meercats, and some months later something near the normal density of population was restored.

(4) The migration of meercats to an area in which eradication had been carried out does not take place in the form of a general movement of a section of the population from the adjoining untreated ground, but it occurs in the form of a steady infiltration by individuals looking for new hunting-ground. Since the new hunting-ground affords adequate shelter by merely opening up and cleaning out existent burrows, the invaders prefer to remain in the new area.

(5) The distance over which *Cynictis* and *Geosciurus* may migrate is not known. In the case of *Suricata*, it is known that it migrates over long distances. But that migration of *Cynictis* and *Geosciurus* from colony to colony over short distances, normally occurs is obvious from the fact, that colonies left or abandoned by meercats of their own accord become inhabited again later. It seems also that constant movement by individuals or families takes place from colony to colony, even in the same hunting-ground, and that migration is not due entirely in the case of *Cynictis* and *Geosciurus* to exhausted food-supply.

(6) During the last visit to the two farms on which the experiments had been carried out, seven places, where colonies had been dug up and totally destroyed, were visited, and in not one instance had warrens been dug again on those sites.

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In 1936 Dr. Thomas gassed, dug up, and completely destroyed all the colonies in an area about ten morgen in extent, near Oden-daalsrust. On subsequent visits by him and myself it was found that the whole area was invaded by meercats, and that they had dug their warrens on the sites of the colonies that had been destroyed. The fact that this did not happen on either of the two farms Beestekraal or Philip is owing to the facts that the areas were big and that warrens were available by merely cleaning them out, whereas in the other case no such warrens existed, and advantage was taken of the loose soil of the old colonies in which to dig fresh burrows.

(7) An attempt was made to estimate the number of meercats on the farms Beestekraal and Middagson.

One can assume that in the 65 colonies, that remained closed up to 3rd March, and the 21 which were closed for a few days, the meercats in them at the time of gassing were killed. Only in 57 of these colonies were meercats seen to enter prior to gassing. The actual number of meercats seen to enter the colonies can thus be regarded as the minimum destroyed, i.e. *Cynictis* 97, *Geosciurus* 37, *Suricata* 7.

In addition to those the following meercats were either shot, trapped, or captured in some way: *Cynictis* 53, *Geosciurus* 58, *Suricata* 10.

To the above totals may be added the number of meercats seen to enter the colonies found reopened after the initial gassing, and prior to the revisit.

The totals are therefore:—

	<i>Cynictis.</i>	<i>Geosciurus.</i>	<i>Suricata.</i>
Assumed killed by gassing.....	97	37	7
Trapped, shot, etc.....	53	58	10
Escaped gassing.....	16	11	12
TOTAL.....	166	106	29

These totals of course represent the absolute minimum of meercats that were on the two farms, as no consideration was taken of those that were killed in the colonies into which no meercats were seen to enter. If one makes an allowance for these on a proportional basis, the following figures are obtained, viz.: the 86 colonies that remained closed may have harboured 146 *Cynictis*, 55 *Geosciurus* and 9 *Suricata*.

Likewise on the same basis then 29 colonies which were found reopened before being revisited, harboured about 25 *Cynictis*, 27 *Geosciurus* and 29 *Suricata*. Some of these, however, were trapped, so that some allowance must be made for that. It is estimated that seven *Cynictis* were trapped and already accounted for, so that the total for the *Cynictis* becomes 18. The grand total therefore becomes: *Cynictis* 184, *Geosciurus* 139, *Suricata* 58.

These totals may be regarded as a fair and still conservative estimate of the meercat-population on the two farms, cognisance being taken of the fact that more meercats were probably killed by gassing than were counted and seen to enter the colonies prior to gassing.

On the other hand again it may be that a certain percentage of those that escaped the gassing were probably trapped at some other colony.

If these totals are acceptable as a rough estimate, then the density on the two farms, 2,400 morgen in extent, works out at 1 *Cynictis* to 13 morgen, 1 *Geosciurus* to 17, 1 *Suricata* to 40 morgen.

C. Extermination of Meercats on Infected Farms, as a Practical Measure of Rabies Control.

As a consequence of the promising results obtained in the experimental destruction described above at Beestekraal and Philip, the Department of Agriculture was prevailed upon to undertake the extermination of meercats on infected farms as a practical control measure. Thus, this afforded a further opportunity of improving the technique, and making further observations under rigorous field conditions.

A Stock Inspector was appointed to undertake the work under the author's supervision. The labour and working-equipment consisted of eight natives, three Schoeman double-action pumps, the necessary supplies of Cyanogas, two hundred 3-in. gin traps, six spades and a motor-van. The party camped near the site of operations, so that there was a minimum of time lost going to, and coming back, from, work.

Procedure.

The localities in which outbreaks of rabies occur are treated in sequence. A preliminary inspection is carried out, to establish the probable extent of the infection and therefore the area to be treated. This is based on the occurrence of colonies, whether there is a break in their continuity or not, the topographical features, etc. These points will be more fully illustrated when the infected areas are described.

As soon as this is completed a programme is drawn up and the whole area is divided into sections, which are to be treated in sequence.

Operations are then started and carried on according to the method already explained. The area is traversed in strips to locate the colonies, and gas them. This is followed by systematic inspection and trapping, until no meercats are left.

A daily report is drawn up, and submitted, by the Stock Inspector. Certain essential data are extracted from this report and summarized in table-form, so as to show in column (1) the number of the sections, corresponding to the number on the sketch-map, of

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the area to be treated; column (2) the date; (3) the number of colonies found and treated; (4) the total number of colonies opened by meercats on the day following gassing; (5) the number of traps set and the number of meercats caught; (6) the number of colonies in which warrens are found open on the second day following gassing, and (7) the number of traps set and the result; (8) the number of colonies inspected and found open at the periodic inspections, giving the dates on which these were gassed; (9) the number of traps set and the result, and finally (10) the result of a final inspection over the whole area with the number of colonies opened, the number of traps set, and the number of meercats caught.

The daily reports also include the number of meercats seen, particulars as to age, pregnancy, species, with stomach contents, etc., of the meercats trapped.

(1) MARAH-WAAIKRAAL AREA: BLOEMFONTEIN DISTRICT.

11.2.39-27.3.39.

The first destruction raid undertaken in this new campaign was the Marah-Waalkraal one. Rabies was diagnosed in a *Geosciurus* at Marah on 11.2.36 and at Waalkraal in a dog on 20.9.38. At the time of the outbreak at Marah, suspected cases were reported in yellow mongooses near the railway station of Sannahspost.

Description of the Area.

(Refer to Map No. 2).—The area borders on the Modder River. A weir across the river, situated near the railway line, causes damming of the water as far back as, and sometimes beyond, Besemkop and thus form an impassable barrier to meercats. Two spruits forming vleis run across the area to join each other on the farm Newlands. The whole area consists of rather flat hillocks, which rise gradually from the water courses. There are no hills except for a stony ridge on Valle.

The vegetation, consisting of mixed grasses, was dense on account of copious rains; 10 ins. was recorded during the latter half of January. The hillocks are extensively cultivated for mealies. Soil erosion is bad on the farms Woonhuis and Goupoud.

Extent of the Infection.

The Modder River, which forms the Eastern boundary of Marah, where the first outbreak occurred, was considered to be the limit of the infection on that side, as the river at that part is impassable to meercats.

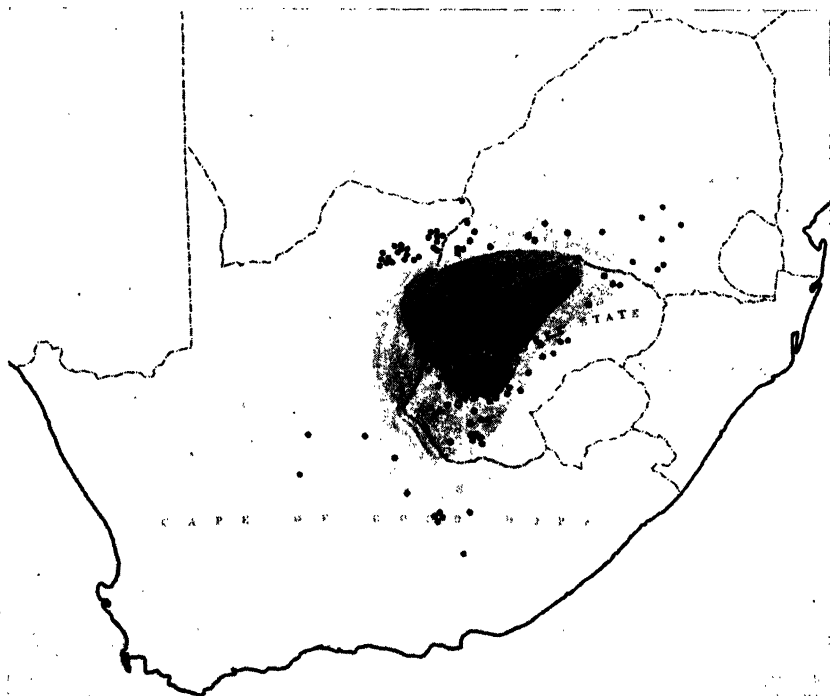
On account of the infection on Marah, and the suspected cases that were reported at Sannahspost railway station, and the outbreak at Waalkraal, the triangular area thus formed with Klipkraal in the centre, was considered the centre of the infection.

The majority of colonies was located along the two vleis running on either side of the station, one through Ems, Waaikraal, etc., and the other along the boundaries of these farms, involving Jacobusgeluk and Sannahspost farm. Further colonies were located on Valle, Rust-en-Vrede and Bourdillon along the river, and at the foot of the low ridges. At Woonhuis, Goupond and Rampani where soil erosion was prevalent, and on the hillock stretching towards the station, only a few colonies existed on the hillock between the two vleis and on the hillock on Meyersgeluk, Baden, and Kromdraai.

Hence the infection was considered to be among the meercats that stayed along the Modder River, and the two vleis referred to above, involving the whole are indicated on the sketch map.

Table 7 is a summary of the work done in this area.

Map No. 1.

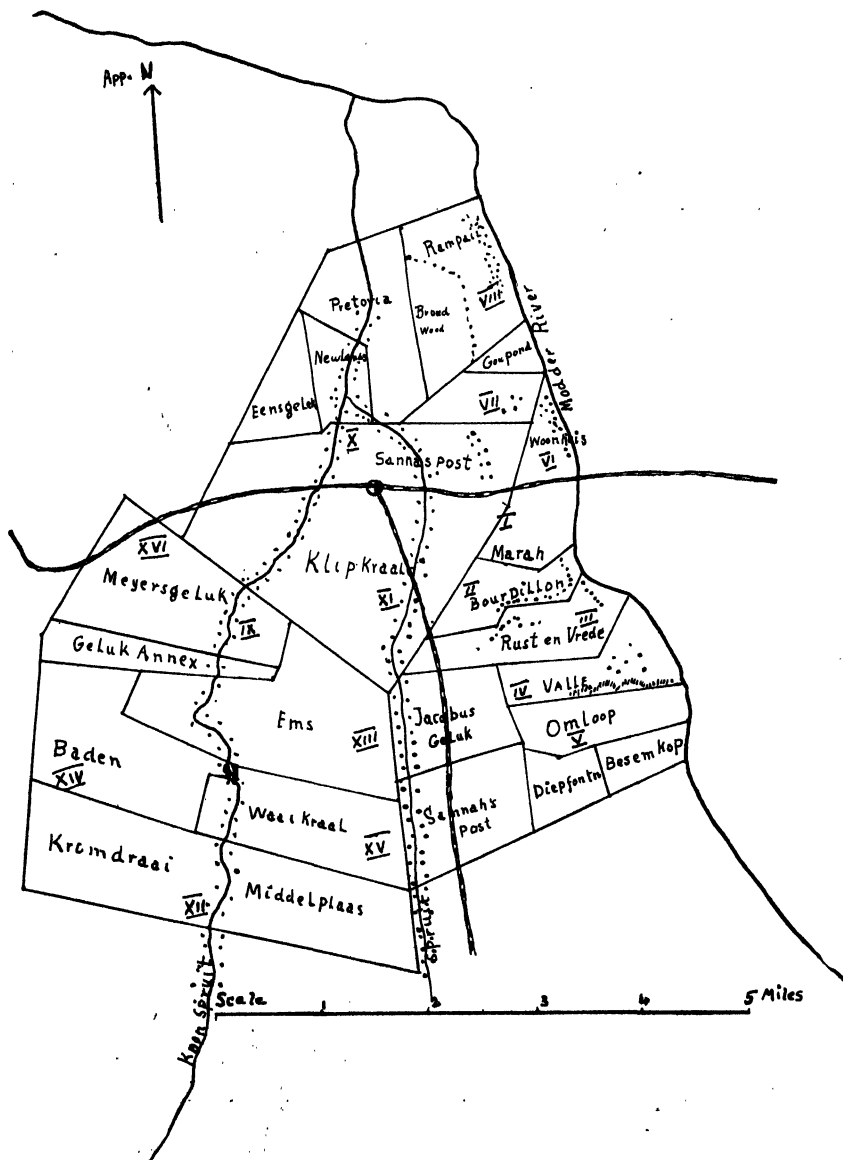


Skeleton Map of the Union of South Africa, showing:—

- (a) Individual farms on which infection has been proved to occur between 1928-39. Whether one case of rabies or several have occurred during that period, the farm is represented by one dot only.
- (b) The estimated population density of *Cynictis*. The dark central area represents an estimated density of one per ten morgen or less, the lighter shades of one per 10-20 or more morgen, and finally 1 per 50 or more morgen. Note the localised areas and the frequency of outbreaks corresponding with the density of *Cynictis*.

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Map No. 2.
SKETCH-MAP OF MARAH WAAIKRAAL AREA.



Reference:—

- Vleis, showing where the majority of meercat colonies were located.
- x Points where rabid animals were found and suspected cases occurred.
- I, II, etc. Represent the sections treated in sequence.
- Meercats were exterminated over the whole area.

No. of Section.	Date.	Number of Colonies Gassed per.	Number of Colonies open at final Inspection of whole Area.			
			Colonies Opened.	Burrows Opened.	Meercats Caught.	
I.....	11/2/39	12				
II.....	13/2/39	18				
III.....	14/2/39	5				
IV.....	15/2/39	5				
V.....	16/2/39	5				
VI.....	17/2/39	4				
VII.....	18/2/39					
VIII.....	20/2/39	7				
	21/2/39					
IX.....	22/2/39	17				
	23/2/39	13				
	24/2/39	15				
X.....	25/2/39	11				
XI.....	27/2/39	10				
	28/2/39	7				
	1/3/39					
	2/3/39					
	3/3/39	10	colonies before gassing.			
	4/3/39	4				
	6/3/39					
XIII.....	7/3/39	3				
XIV.....	8/3/39	6				
XV.....	9/3/39	12				
	10/3/39	6				
XVI.....	11/3/39	3				
XII.....	13/3/39					
	14/3/39	7				
	15/3/39	6				
XV.....	16/3/39	9				
	17/3/39	8				
	18/3/39	3				
	20/3/39					
	21/3/39		XI.....	34	114	34
	22/3/39		and XIII..	37	120	33
	23/3/39		VI.....	24	104	38
	24/3/39		and I.....	24	115	29
	25/3/39		and X.....	25	124	45
	27/3/39		I and VIII	19	108	17
			and XV..	7	46	10
		210				
			170	731	206	

Remarks.

(a) At the outset it must be stated that this was the first time such a large area had been treated, and coupled with the inexperience of the gassing squad, labour shortage (only two boys being employed on some days), the work was carried out under difficult circumstances.

(b) From the number of colonies found reopened at the final inspection, i.e. from the 20th to the 27th, and the number of meercats trapped during that period, the results of the gassing and subsequent trapping appear to be disappointing.

(c) That out of 210 colonies, 62 were found reopened on the day following the gassing and 39 on the second day, and 63 and 31 meercats trapped respectively indicate that the gassing was not as effective as could have been expected. The conditions mentioned under (a) and the wet ground were responsible for this.

(d) In a great many instances birds were trapped at warrens which were found reopened. These were later identified as *Myrmecocichla formicivora*, or the Anteater Chat. Dr. Austin Roberts of the Transvaal Museum, who kindly identified these birds, added the following description of their habits: "This is purely a South African species, occurring in open ground, and I have procured them even as far north as Ngamiland and Ondonga districts in S.W.A. It feeds on insects, and nests and roosts in burrows and in the roofs of burrows made by antbears and meercats, so that its being trapped in the way you mention is not unexpected".

This bird's habit of reopening warrens that have been gassed and closed somewhat confused the issue, in that in many instances warrens that had been opened by them were attributed to the work of meercats.

(e) The trapping during the last seven days greatly reduced the number of meercats in the area. A final inspection was made in the areas where the majority of the colonies was located, i.e. along the Modder River, the two vleis, and the hillock on Woonhuis and Klipkraal, the vicinity of Sannaspost Station. In all only two *Geosciurus* were seen, and seven or eight colonies were found open.

All this indicates that the number of meercats on the farm was reduced to an almost negligible amount.

(2) TAFELKOP—STERKFONTAIN: BLOEMFONTEIN DISTRICT.

29.5.39-8.7.39.

Outbreaks of rabies in *Cynictis* occurred at Tafelkop on 8.10.38, and at Sterkfontein on 9.12.38. On the latter farm mongooses behaving strangely were seen for some time prior to the outbreak. The localities where the infected mongooses were discovered are about 9 miles apart.

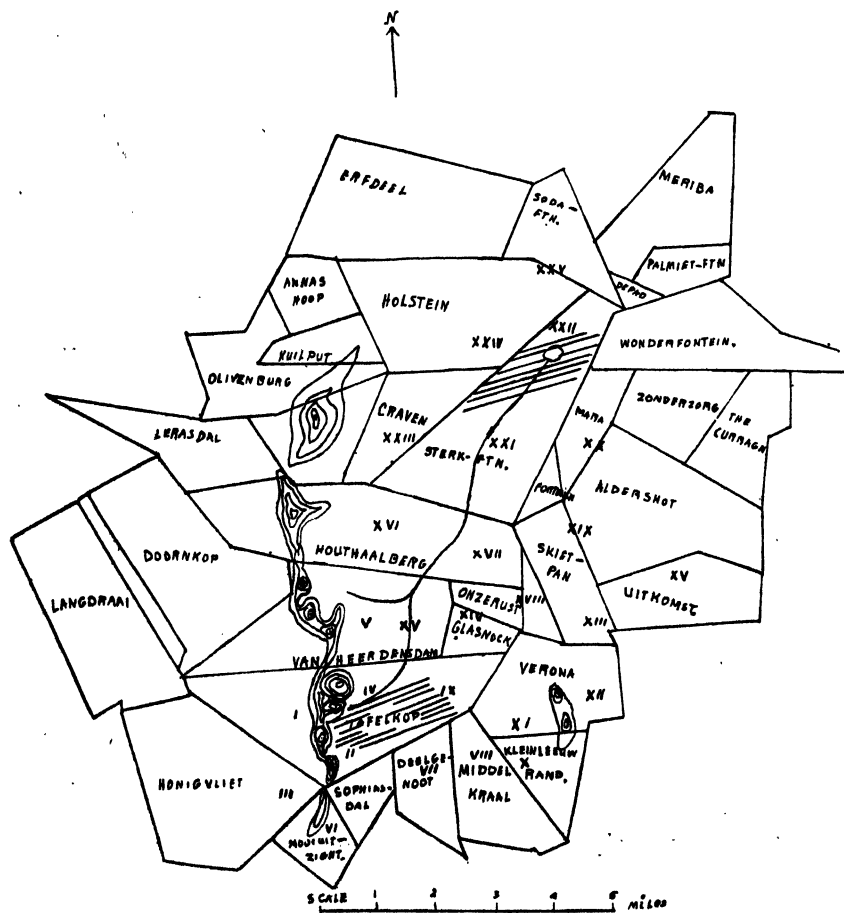
STUDY AND CONTROL OF THE VECTORS OF RABIES.

The Description of the Area.

(Refer to Map No. 3.)—This centre is situated in the South-western part of the Bloemfontein district on the Fauresmith border. The area is marked by a loose range of high hills running from north to south. The altitude of the highest point, Tafelkop, is 5,312 ft., while the altitude of the plains is only 4,500 ft. Small ridges of stone kopjes are scattered over the farms Deelgenoot, Verona, Palmira, Fortuin, Mara, etc. Situated on Sterkfontein is a large dry pan, into which leads a shallow vlei, rising on Tafelkop, with tributaries originating from the range of high hills.

Map No. 3.

TAFELKOP-STERKFONTEIN: BLOEMFONTEIN DISTRICT.



Reference:—

I, II, III, etc., indicate subsections to which reference is made in the text.

===== Indicate area where carcasses of meercats were found.

On inspection, colonies were found along the vleis and extending upwards to the foot of the high hills, and along the scattered kopjes on the western part of the area. The infection was considered to extend from Tafelkop to Sterkfontein along the vleis, and outwards towards the hills. Extermination of the meercats was, therefore, undertaken over the area on the east of the range of high hills from Mooiuitzicht to Sterkfontein, up to the scattered hills on Deelgenoot, Verona, Palmira, Fortuin, Mara. The area was approximately 18,600 morgen in extent.

Results.

See Table 8.

Remarks.

The results on the whole seem very satisfactory.

(a) Out of a total of 1,591 meercat colonies treated, only 71 were found reopened on the day following gassing and 34 on the second day. This indicates that gassing is the most effective means of killing the majority of the meercats, especially in view of the fact that only 57 and 46 meercats were trapped on the two days following the gassing.

(b) 605 Colonies were found reopened at subsequent visits, i.e. less than half of the colonies treated. For the first 25 days a record was unfortunately not kept of the number of colonies visited at the periodic inspections. During the 69 days on which this record was kept, 3,954 visits to colonies were made, which shows that each colony, besides the inspection on the day subsequent to the gassing and the second day thereafter, was inspected at least a further three times.

(c) The success obtained in reducing the number of meercats is clearly shown in that, during the final inspections of the colonies, when almost half of the 1,591 colonies were visited, only 104 colonies were found reopened, at which only 23 *Cynictis*, 3 *Suricata* and 43 *Geosciurus* were trapped.

(d) As in the case of the previous area, a considerable number of birds (the total being 222 for the whole area), and 90 mice and rats were trapped. These birds and small rodents are, therefore, responsible for the reopening of a large number of warrens, and they should be regarded as an important modifying factor when the number of colonies found reopened, at the subsequent and final inspections, is taken as a measure of the amount of success attained.

(e) An important fact, to which little significance has been attached, is the number of carcasses of all three species of meercats in various stages of decomposition that have been found on the infected areas, at colonies or in close vicinity to them. The localities in which these were found in the Tafelkop-Sterkfontein area rouse suspicion that these animals died of rabies, and the presence or absence of such carcasses may be an indication of the extent of the infection.

Carcases of meercats were found on the following points marked on the map: in areas VIII, IV, IX, V and XV, eleven of *Cynictis* and one of *Geosciurus*; while in areas XXI, XXIII, XXII, and XXIV, twelve of *Cynictis* and two of *Geosciurus*. Yet none was found in the other areas. It may be assumed, therefore, that two distinct centres of infection were present in this area, coinciding with the places where the infected animals were actually found.

(3) SUNNYSIDE: BLOEMFONTEIN DISTRICT, 13TH TO 29TH JULY, 1939.

On 4th May, 1939, an outbreak of rabies was diagnosed in a cow, which grazed in the camp marked No. III on the sketch, and on the 21st of the same month a rabid *Cynictis* was found in the same camp at the spot marked "Y Cyn".

Description of Area.

(Refer to Map No. 4.) The farm Sunnyside, situated about three miles from Bloemfontein, is bounded on the west and north-west by small holdings of 5 to 10 morgen each in extent. The watermain for Bloemfontein water-supply from the Modder River runs over the farm. The farm Vaalbank Suid adjoins Sunnyside on the north. A dry spruit arising on Bloemfontein runs through Camp III on Sunnyside and through Vaalbank Suid. To the east of the spruit the country is very level, while on the west the land is higher and stony ridges are found.

Location of Meercat Colonies.

One was struck by the number of warrens in the loose soil, which covered the water-main. Groups of warrens, which could hardly be termed colonies, existed every few yards. The warrens swarmed with *Cynictis*. On one occasion while motoring along the main on the farm Sunnyside, 11 *Cynictis* were seen escaping into the warrens. Colonies were also frequent along the dry spruit and especially on the higher ground to the west on Vaalbank Suid. But none was found on the plots, and only scattered ones on the rest of Sunnyside and Vaalbank.

On account of the fact of the infected cow being in Camp III and that a rabid *Cynictis* was found near the water main, it was considered that the infection existed in the meercats along the main and those in Camp III, and possibly amongst those on the hillock on Vaalbank Suid to the west of the spruit. The localities where a further rabid *Cynictis* and the carcasses of meercats were found, to some extent supported our assumption of the extent of the infection.

During the gassing operations an infected *Cynictis* was found at the spot "Z Cyn", and eleven carcasses of *Cynictis* in areas II and III all near the water main, while those of four *Cynictis* and of one *Geosciurus* were found in area IV along the dry sloop and to the west of it.

No. of Section.	Date.	Number of Colonies Gassed	Colonies open on the Inspections.		Number of Traps Set and Result.	
			Number of Colonies Open.	Warrens Open.	Number of Traps.	Number of Meercats Caught.
I.....	31/3/39	19				
	1/4/39	15				
II.....	3/4/39		2	7	5	0
	4/4/39	9	9	14	10	6
	5/4/39	7	3	7	7	5
	6/4/39	18	3	6	6	1
III.....	11/4/39	20	8	95	57	8
	12/4/39	13	21	84	83	19
IV.....	13/4/39	15	23	139	89	30
V.....	14/4/39	17	14	52	45	11
	15/4/39	9	15	61	47	11
VI.....	17/4/39	48	9	63	37	5
	18/4/39	17	10	52	37	16
VII.....	19/4/39	19	33	186	91	20
	20/4/39	13	33	155	96	31
	21/4/39	21	26	120	96	37
	22/4/39		26	115	96	22
	24/4/39	18	25	92	73	13
	25/4/39	15	26	85	85	73
VIII.....	26/4/39	15	12	30	28	4
	27/4/39	13	8	29	26	16
	28/4/39	15	15	4	38	26
IX.....	1/5/39	23	25	58	49	18
X.....	2/5/39	13	23	98	83	25
	3/5/39	7	19	77	61	36
XI.....	4/5/39	5	19	69	67	16
	5/5/39	13	7	25	24	6
XII.....	6/5/39	30	4	5	4	2
	8/5/39	25	9	46	38	3
	9/5/39	17	12	68	57	19
XIII.....	10/5/39	24	7	31	29	15
	11/5/39	24	8	24	23	8
XIV.....	12/5/39	10	10	30	27	5
	13/5/39	16	15	39	36	12
	15/5/39	27	25	65	60	3
XV.....	16/5/39	17	14	32	32	21
	17/5/39	19	18	46	42	23
	18/5/39		16	48	46	20
XVI.....	19/5/39	25	9	25	20	8
	20/5/39	22	14	46	46	18
	22/5/39	23	9	52	40	11
XVII.....	23/5/39	19	20	83	58	22
	24/5/39		9	21	20	16
XVIII.....	25/5/39	31	16	53	45	22
	26/5/39	8	14	74	64	21
XIX.....	27/5/39	19	12	73	54	17
XX.....	29/5/39	10	12	33	33	6
XXI.....	30/5/39		6	21	20	13
	31/5/39		7	25	23	10
	1/6/39	40	10	35	31	15
	2/6/39	34	4	9	9	6
	3/6/39	15	4	9	9	8
	5/6/39	29	11	33	28	13

(CONTINUED OVERLEAF.)

ber of Traps and Result.		Number of Colonies open on Periodic Inspections.				Number of Traps Set and Result.	
of	Number of Meercats Caught.	Date Colony Gassed.	Number of Colonies Inspected.	Number of Colonies Open.	Warrens Open.	Number of Traps.	Number of Meercats Caught.
—	—	29th- 3rd	(63)	6	27	25	17
—	—	1st- 5th	(61)	5	15	13	12
—	—	1st- 6th	(51)	6	21	21	3
—	—	2nd- 7th	(69)	6	10	10	10
—	—	10th- 6th	(42)	6	10	10	8
—	—	4th- 9th	(63)	7	34	30	3
—	—	5th-10th	(58)	8	25	24	11
—	—	6th-12th	(61)	8	24	23	14
—	—	6th-13th	(57)	10	26	23	14
—	—	9th-14th	(52)	18	39	32	21
—	—	9th-15th	(52)	18	39	32	11
9	—	10th-15th	5(1)	3	15	13	0
—	—	10th-17th	(42)	6	28	26	9
—	—	12th-19th	(63)	11	38	37	18
—	—	13th-20th	(62)	5	15	13	11
—	—	16th-22nd	(52)	9	20	18	11
—	—	13th-22nd	(33)	9	20	18	6
—	—	22nd-24th	(51)	19	43	38	9
—	—	22nd-24th	(60)	7	21	20	15
—	—	23rd-26th	(64)	7	17	17	10
—	—	23rd-27th	(82)	8	22	22	15
—	—	24th-28th	(63)	2	12	10	10
—	—	24th-28th	(33)	2	10	10	10
2	—	27th-30th	(64)	7	23	22	4
—	—	26th- 1st	(52)	13	39	37	18
—	—	—	—	—	—	—	—
46			(3,954)	605	3,335	2,602	1,017

Number of Traps Set.	Results.	SPECIES.			
		<i>Cynictis.</i>	<i>Suricata.</i>	<i>Geosciurus.</i>	Other Animals.
77	27	5	1	21	—
89	19	10	—	8	1
89	20	6	2	11	1
73	7	2	0	3	2
328	73	23	3	43	4

NUMBER OF ANIMALS AND BIRDS TRAPPED.

and rats..... 90
..... 220

Number of Section.	Colonies open on inspections.		Number of Traps Set and Result.	
	Number of Colonies Open.	Number of Warrens Open.	Number of Traps.	Meercats Caught.
.....	4	7	-	-
	15	38	-	5
	18	36	36	20
	10	23	21	12
	12	34	30	27
	8	26	26	18
	8	26	26	11
	17	27	25	10
	19	35	35	13
	39	57	55	29
	21	55	55	34
	56	157	138	48
	56	120	117	24
	283	641	600	233

ber of
and R

own Commonage.

or of ms.	Number of Traps Set and Result.		Number of Colonies open on Periodic Inspection.				Number of Traps Set and Result.	
	Number of Traps.	Number of Meercats Caught.	Date Colonies Gassed.	Number of Colonies Inspected.	Number of Colonies Open.	Number of Warrens Open.	Number of Traps.	Number Meerca Caught
	18	10						
			3rd- 4th	(82)	18	56	51	21
			3rd- 5th	(137)	17	40	40	27
			3rd- 7th	(144)	19	41	41	31
			3rd- 8th	(179)	25	66	65	27
			3rd- 9th	(198)	24	61	61	18
			2nd-10th	(175)	25	72	69	19
	18	10		935	128	336	332	145

; 114 traps set; result 74 meercats trapped.
ult 29 meercats trapped.

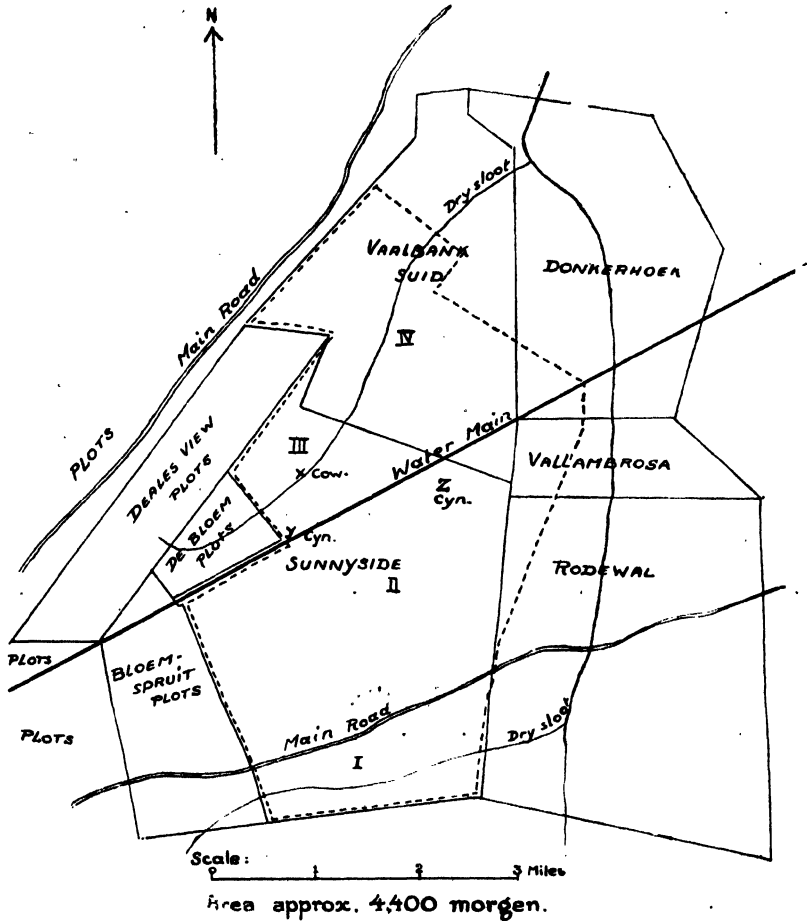
ED.

ber c	132
raps	111
set.	11
	7
	261
77	
89	20
89	3
73	5
	1
328	
	29
BER (
and)	

The area mapped out to be treated, was the whole of Sunnyside, the portions of Roodewal and Vallambrosa which adjoin Sunnyside and that portion of Vaalbank Suid on which the infection was thought to exist. The area treated is marked by a broken line on the sketch.

Map No. 4.

SUNNYSIDE: BLOEMFONTEIN DISTRICT.



Reference:—

- — — — Shows area in which meercats were eradicated.
- × Cow Position where infected cow was found.
- Y & Z Position where infected yellow mongooses were found.
- I, II Indicate sections into which the area was divided for purposes of gassing.

STUDY AND CONTROL OF THE VECTORS OF RABIES.

Results.

See Table 9.

Remarks.

(1) Out of the 429 colonies gassed, fourteen were found upon the following day.

(2) As the area was comparatively small, the colonies in the area, which were considered actually infected, were visited at least three times subsequent to the third day after gassing.

(4) EDENBURG COMMONAGE.

The following outbreaks of rabies have occurred on the Edenburg Commonage. In April and August, 1933, the disease was diagnosed in two *Cynictis* found at the points marked X on the sketch map of the Commonage. In June, 1939, a further case occurred in a *Cynictis* at the point marked XI, and a week later another suspected case in a *Cynictis* occurred in the same spot.

Description of Area.

(Refer to Map No. 5.) The area treated consisted mainly of Karroo-bush covering the fairly flat country; in Area I a low ridge of hills extends from north to south, while in Area II an isolated koppie exists. Two vleis traversed this area, in which colonies were plentiful. The limits of the infection were considered to be along the two vleis, as the hillocks on either side contained only a few colonies which were widespread over the area. The carcasses found in the veld confirmed this. Carcasses of two *Cynictis* and one *Geosciurus* were found in Area II, while in Area IV, those of a *Cynictis* and a *Suricata* were found.

Results.

The results are summarized in Table 10.

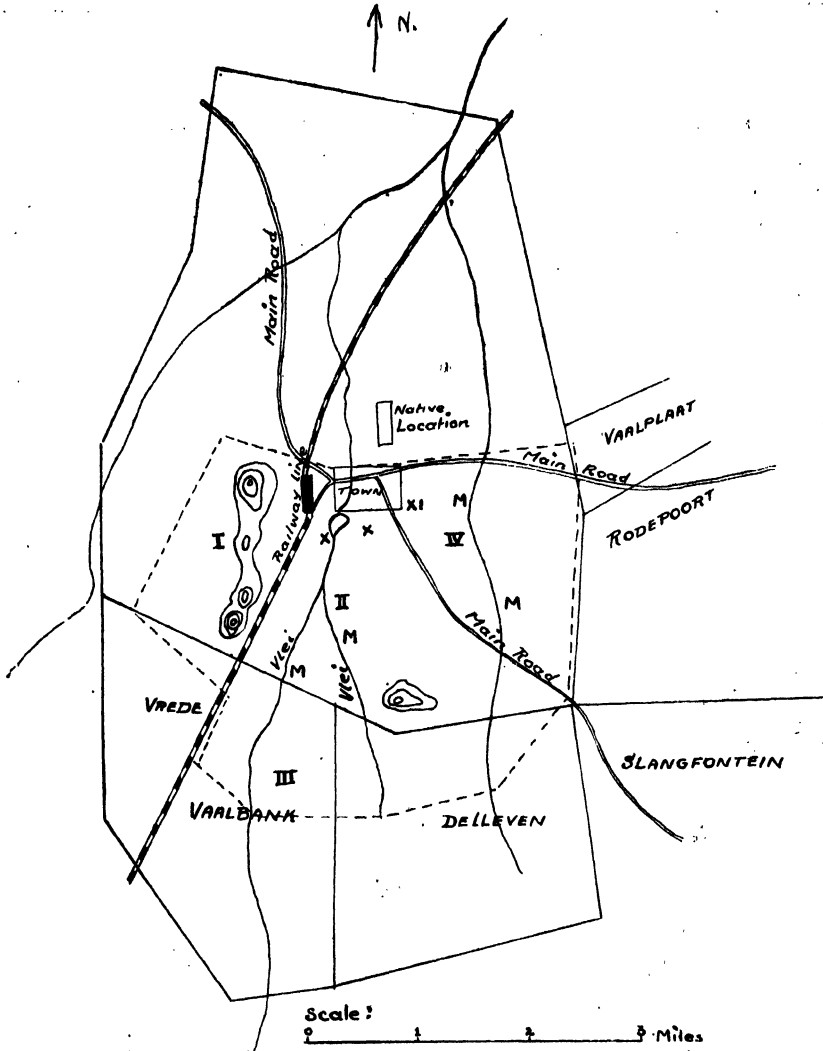
Remarks.

The results invite little comment, as they are practically the same as those of the areas done previously. Three weeks later a second visit was paid to this area to determine to what extent immigration of meercats to the area had taken place. The whole area was gone over twice during two successive days, and traps were set at all warrens that were found to have been re-opened.

The results of the trapping were as follows: 217 colonies were visited, of which 60 were found re-opened, and 160 warrens had been cleaned by animals. 71 meercats were trapped: *Cynictis* 36, *Geosciurus* 21, *Suricata* 15, *Ictonyx* 4, *Pedes caffer* 1, and *Anteater* 7.

These results show that immigration of meercats, once an area has been cleaned of them, does not take place very rapidly to such an area, from which, it may further be concluded, that it is possible to keep such an area free from meercats by trapping only.

Map No. 5:
EDENBURGH COMMONAGE.



Reference:—

- x x Points where infected Cynictis were located in 1933.
- x1 Points where infected Cynictis were located in 1939.
- M Approximate position of meercat carcasses.

(5) TROMPSBURG COMMONAGE.

Description of Area.

(Refer to Map No. 6.) This area includes the whole of the Commonage, and the farms Spes Bona and Middelfontein. The area consists of semi-karoo veld, with isolated low hill-ranges and kopjes. The spruit running from South to North through the area is very shallow and broadens out into vleis, especially near the southern boundary. Weirs across the spruit result in water pools, existing almost throughout the year.

Extent of the Infection.

No less than eight cases of rabies had been diagnosed in Viverrids on the commonage from June, 1932, to July, 1939. The rabid animals were all found in an area, two miles square, on the southern side of the village. An infected Genet at Spes Bona was found near the commonage boundary. The infection was considered to extend amongst the Viverrids on the southern half of the Commonage, and probably on those portions of the farms Spes Bona and Middelfontein adjoining the Commonage.

In 1937 a careful survey was made of the infected portion of the Commonage. The positions of the larger colonies and groups of colonies were recorded on a sketch-map, to assist in recording the results of extermination experiments.

The object of the experiment was to determine to what extent gassing alone was successful. At the conclusion of the experiments, it was considered that all the meercats had been exterminated except a few, which took refuge in the kopjes. As a further case of rabies occurred in July 1939, the experiment must be considered as having been unsuccessful.

When the area was traversed in the recent attempt to eradicate the meercats, a considerable number of colonies was still found closed and many which had been reopened were unoccupied.

It is therefore, essential, before any measure of success in eradicating rabies in an infected area can be obtained, that all meercats in such an area should be exterminated.

Results.

The Results are summarized in Table 11.

Remarks.

(a) The carcasses of dead animals were found as follows: In Area II that of a *Cynictis*, and those of a *Suricata* and four *Geosciurus* in Area V.

(b) 266 Colonies were fumigated, and of these 17 were found reopened within two days of the gassing, 11 meercats being trapped in them.

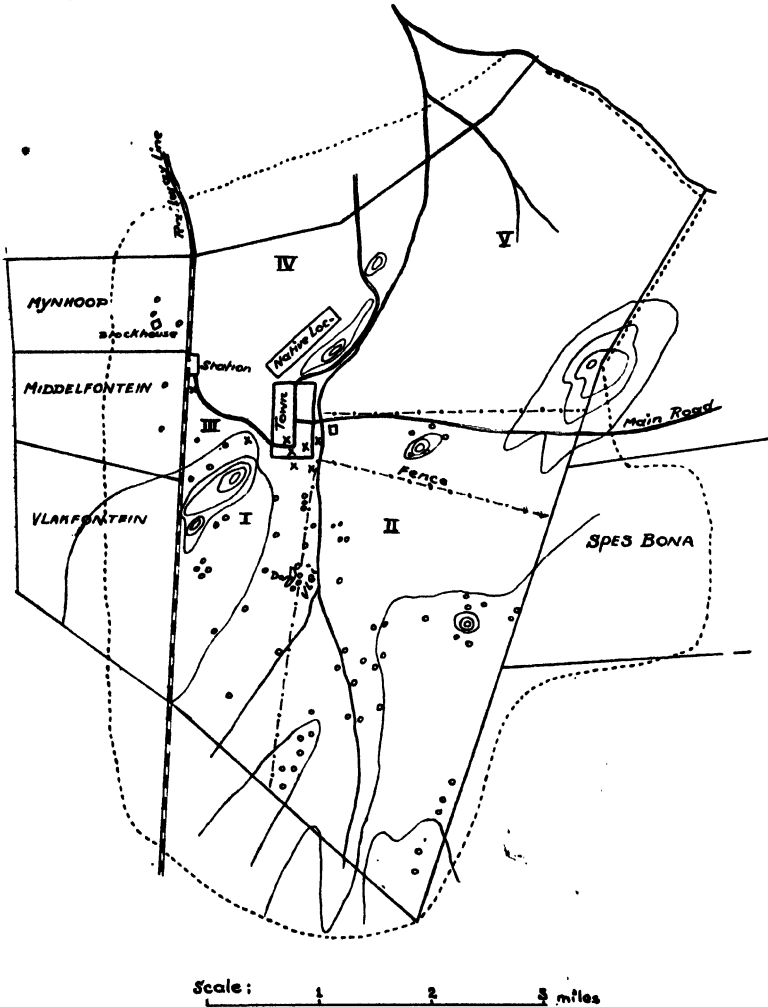
(c) Each colony was inspected at least 8 times during the 19 days.

(d) During the final inspection the Areas Nos. I, II and III, marked as A on the summary, considered to be the centre of the infection, were very carefully inspected. The results of the last four

Number of Section.	Number of Colonies Open on Periodic Inspection.		Number of Traps Set and Result.	
	Number of Colonies Open.	Number of Warrens Open.	Number of Traps.	Number of Meercats Caught.
I.....	—	—	—	—
	2	2	10	2
II.....	4	9	9	7
	3	6	6	4
	3	6	6	4
III.....	2	2	2	2
	16	33	33	10
	13	28	28	21
	12	24	24	15
	7	15	15	14
	7	19	19	14
IV.....	7	15	15	9
	10	22	21	7
V.....	9	21	21	4
	7	21	21	14
	6	14	14	10
	18	28	28	16
	18	30	30	19
	11	16	16	4
	19	46	46	10
	5	8	8	4
	20	46	46	33
	5	10	10	0
	20	46	46	11
	223	485	484	250

days' inspection, when 159 colonies were visited (of which a few only were found reopened and no meercats trapped) showed that if not all the meercats had been exterminated, then only an odd one might have escaped. The extermination of the meercats must, therefore, be considered as having been successful.

Map No. 6.
TROMPSBURG COMMONAGE.



Reference:—

- × Denotes points at which infected *Cynictis* were found at different times.
- o o Approximate position of colonies. A detailed survey was made of areas I, II and III in 1937.
- Boundary of area in which meercats were exterminated.

TABLE 12.
Summary of Work performed on the Five Infected Farms, and the Expenditure involved.

Area.	Approximate size of Area in Morgen.	Number of Colonies Gassed.	Number of Meercats trapped.			Number of days taken to exterminate the Meercats.	Amount of Cyanogas Used.	Cost of Cyanogas.	Wages and Rations of Labourers.	Total Cost.
			<i>Cynictis.</i>	<i>Suricata.</i>	<i>Geosciurus.</i>					
Marah, Wasikraal.....	6,850	210	150	47	364	38	175	£ s. d. 10 18 9	£ s. d. 21 3 10	£ s. d. 32 2 7
Tafelkop-Sterkfontein....	18,300	1,512	384	119	648	79	513	32 1 3	80 10 9	122 12 0
Sunnyside.....	4,400	429	141	14	105	16	75	4 10 9	16 8 1	20 18 10
Edenburg Com.....	3,100	279	168*	26*	132*	13*	37	2 6 3	16 5 0	18 11 3
Trompsburg Com.....	8,250	266	151	32	67	22	63	3 13 9	18 19 10	22 13 7
TOTAL.....	40,900	2,696	994	238	1,296	165	863	55 10 9	150 7 6	208 18 3

* Include the number of meercats trapped on a subsequent visit for two days.

The cost of Cyanogas is calculated at 1s. 3d. per lb., a price quoted to Municipalities.

The wages of a native labourer amounts to 2s. 5d. per day plus 2½ lb. of mealie-meal.

The Salary of the Supervisor is not included in the column of expenditure; it amounts to £1 per day.

The above data, when calculated on a basis of 1,000 morgen, gives the following details approximately:—

The number of colonies was.....	66	This figure may be taken as representative of the number of colonies on average infested ground.
The number of <i>Cynictis</i> trapped was.....	22	
The number of <i>Suricata</i> trapped was.....	6	
The number of <i>Geosciurus</i> trapped was.....	31	

The amount of Cyanogas used was 21 lb.

The number of days taken in gassing was 4.

The total cost amounted to £5. 1s. 0d., and if the salary of the Supervisor is included, £9. 1s. 0d.

PART III.

CONCLUSIONS.

A. THE NECESSITY OF DESTROYING MEERCATS AND THE VALUE OF STUDYING THEIR HABITS AND WARRENS.

In general, as has been pointed out, the control of rabies consists in preventing the rabid animal from biting persons and other animals.

Where the dog plays the principal rôle in the epizootology of the disease, the methods adopted to check dissemination of rabies is comparatively easy, as dogs can be placed under proper restraint by their owners, and ownerless dogs can be rounded up and destroyed. In addition prophylactic inoculation is employed in some countries with success, in spite of the fact that, this method may produce occult carriers.

When the disease is established in wild animals, as is the case in our viverrids, there can be but one way of eradicating the disease, and that is by destruction of the vectors.

Before effective weapons can be devised, something must be known of the enemy, his habits, weaknesses and defences. That is why a study of meercats was a *sine qua non* of any useful work. Not only have these studies shown, that the burrow is a place of refuge to which meercats run when disturbed, and to which they owe their survival in settled areas, but they have revealed, that the burrow is a convenient place, not easily missed, in which these elusive animals can be "run to earth" and completely destroyed.

It is indeed fortunate that the yellow mongoose, which is undoubtedly the most important vector of rabies in this country, can so effectively be attacked and destroyed. If some other free roaming animal, such as the jackal, had been the principal carrier of the disease, then we would have had to face the same difficulties in the control of the disease, as for instance the sheepfarmer has in protecting his stock from this marauding beast.

B. EVOLVING THE MOST EFFECTIVE AND PRACTICAL METHODS OF DESTRUCTION.

(a) Of the various methods tried to destroy meercats, gassing of the burrows with calcium cyanide dust, followed up by trapping, has proved to be the most effective.

The digging up of colonies subsequent to gassing revealed, that it was possible in many instances completely to destroy meercats in their burrows, and where this was not possible the causes of failure were exposed, and remedial measures to overcome them were devised.

Among the causes which may lead to failure or ineffective work must be mentioned—

(i) using a pump not in perfect working order, resulting in bad distribution of calcium cyanide in burrows;

(ii) using poor quality, old, or spent cyanide powder. Good fresh powder should have a very fine pulverulent texture and have a bluish slate colour;

(iii) gassing when the humidity, looseness and gas-absorbing properties of the soil are too high;

(iv) bad circulation of gas in the intricate tunnel maze of a colony, due to the presence of obstructions and long cul-de-sacs;

(v) closing any openings before gas has emerged from them, and finally,

(vi) failure to fumigate for a long enough period, i.e. until powder is seen emerging from all openings before these are closed.

Causes of failure due to equipment and technique can be avoided or remedied, but those inherent to the burrow itself cannot be prevented. If the technique is perfect, therefore, and meercats still escape alive from a burrow it can be assumed, that the cause lies in the burrow, and it would be sheer waste of time and money to fumigate such burrows repeatedly, since the results would probably be the same.

Where only one or two meercats per odd colony escape as seen from the reopened holes, it is therefore far more economic and more effective to set traps and so catch the last surviving animals.

The advantage of this method of gassing combined with trapping is that it is cheap, simple and with care safe to handle, eliminating many elaborate precautions.

(b) This method of gassing combined with trapping has been successfully employed to destroy the meercats in several large areas. Although not considered feasible or necessary in so far as the particular method of rabies-control adopted, an area so cleaned could, if desired, be maintained clean at a minimum cost by continuing trapping indefinitely in this fashion.

To ensure success attention should be paid to the following details:—

- (i), locate all the colonies;
- (ii) comb the veld systematically, to ensure that all the meercats have been chased into the burrows prior to gassing;
- (iii) fumigate thoroughly—bearing in mind the pitfalls mentioned above;
- (iv) close all disused holes and colonies;
- (v) revisit systematically all colonies and set traps where required;
- (vi) continue trapping as long as any holes are being re-opened while operations last in that area.

(i) *Location of all Colonies.*

The importance of locating all the colonies need hardly be stressed, as success in eradicating the meercats in a given area depends largely on the thoroughness with which this is done. Even disused ones should be located and closed. The best method to ensure that all the colonies are located, is for the members of the gassing gang, consisting of from six to eight persons, to walk in extended-rank formation. The space between the men should not be more than fifty to a hundred yards, depending on the denseness of the vegetation. A good procedure to follow to avoid overlapping of areas, or which is more important of skipping portions, is for the flank member to stake or erect temporary beacons at least at the ends of his beat, and at such other points along his patch as may be necessary. These beacons indicate on the return journey, the strip of land previously traversed. Instead of carrying flags etc., it is convenient and just as effective where there are trees and fences, to place tufts of grass on them for beacons. In open country, where antheps are plentiful, the top of an anthep may be removed and an easily recognisable mark is made by replacing it with the inner side upwards.

Both the inhabited and uninhabited colonies should be marked and, if possible, numbered in such a way, that they can be easily relocated and identified at subsequent visits. A suitable method of marking these colonies is by driving a light metal fencing-dropper with a numbered tag on it into the ground near the colony.

(ii) *Ensuring that all meercats are chased into the burrows.*

The system of combing the veld as described above also serves the very important purpose of ensuring that the meercats are chased into their burrows, where they are to be gassed.

Meercats invariably run to their burrows when disturbed in the veld, unless hard pressed or closely chased, when they may seek refuge in any convenient hole. In the Sannahspost area, where extensive mealie fields existed, neglect to comb these fields, where meercats hunted for food, resulted in many of them being absent at the time of the gassing of their burrows, and they had to be trapped afterwards.

(iii) *Fumigating thoroughly.*

Gassing is the quickest and easiest way to kill the meercats, when they are in their burrows. Success in doing so depends on the thoroughness with which it is done. The pitfalls mentioned above should, therefore, always be borne in mind, and the necessary steps should be taken to eliminate them when possible.

Before a colony is gassed, one or two strokes of the pump should be given, to see that the correct amount of powder is forced out. Regular attention should be given to the pump, as regards lubrication and keeping it in perfect working order. The procedure in gassing as described above should be closely followed.

(iv) *Closure of all disused holes and colonies.*

At the farms Beestekraal and Philip, where a careful record of all the colonies was kept, it was found that six out of thirty-five and two out of thirteen colonies respectively, which were unoccupied and deserted at the time of the general survey of the farms, became occupied at a later date. Unless such colonies are closed and revisited later and treated as if they were inhabited, they become the abode of meercats, which would otherwise escape destruction.

(v) and (vi) *Systematic revisiting of all colonies, and the setting of traps.*

White (1932) gave up all hopes of exterminating meercats on a large scale on account of the rapid reinfestation taking place on a farm, even before the gassing operations on that farm were completed.

Thornton (1935) also described the lack of success in destroying veld rodents in connection with anti-plague measures due to neglect to treat deserted and spare warrens.

From the observations made at the farms Beestekraal, Middagson, Philip, Sannahspost, etc., it was concluded that colonies were reopened by (a) meercats which had escaped contact with gas in the burrow and succeeded in digging themselves out; (b) by meercats, that were away at the time of gassing and returned to dig themselves in; (c) by meercats migrating from adjoining untreated ground, finding in their new hunting-ground convenient shelter by merely opening up and cleaning out existing burrows; (d) by meercats visiting colony after colony opening a few holes; (e) by marauding animals like the skunk digging after prey; and (f) by ant-eating chats, which nestle in burrows.

It stands to reason therefore, that if one wishes to exterminate meercats in a given area, one will have to pay very close attention to this most important supplementary method of destroying, viz. trapping. Not only is it the cheapest method of destroying these animals, but it is very effective and can well be used without gassing, when the time factor is not very important.

The following procedure gives the best results.

The area gassed should be revisited the following day, and sufficient traps provided to place at all reopened holes. In practice fifty traps are found sufficient. The person in charge of the trapping is given the numbers allocated to the colonies gassed the day before to serve as a check to himself and to ensure that every colony is found, as cattle may sometimes push the droppers over and the latter can also not be seen easily from a distance.

At all holes and warrens found reopened, traps are set. These are inspected the following day, and any not sprung may be removed and the holes closed, since many burrows are reopened but do not become occupied. The same applies when an animal or bird has been caught, unless there are other holes, which have been found reopened again.

It is essential that the person with the traps follow closely on the heels of the gassing gang.

Since many colonies are re-opened and become occupied as many as three times or more by meercats, which are continually filtering into the area from the untreated adjoining ground, a second and if necessary a third person should be detailed to pay repeated visits at regular intervals to the area already treated in order to trap any animals, that may continue to re-open burrows.

Immigration of meercats takes place soon after an area has been treated, but as the number available in the neighbourhood is gradually reduced by gassing and trapping, the rate of migration steadily decreases, until finally a stage is reached, when the infiltration becomes negligible. It is essential, therefore, that trapping should be continued until all holes, that are being re-opened by meercats, remain closed.

The re-opening of holes by the anteating Chat sometimes causes much trouble, as in many instances it is not easy to distinguish whether the hole has been re-opened by one of these birds or by a meercat. In such cases traps have to be set, and rarely fail to show which of the two is responsible for the re-opening of the holes. As many as eight birds have been trapped in one day.

After the extermination of meercats in any locality by the methods outlined above, it should be a comparatively easy matter, if so desired, to maintain effective control and keep such an area clean with very little expenditure of time and money, by making frequent periodic inspections and setting traps at any warrens that have been re-opened. Especially would this be the case with *Cynictis*, the most important carrier of the disease. This animal, unlike *Geosciurus*, when occupying an old (closed) colony, only opens and uses a few warrens on the periphery; thus the purchase of a large number of traps by the farm owner, who may wish to keep his farm free from *Cynictis*, would be unnecessary.

C. LABOUR, EQUIPMENT AND WORKING COST.

(i) For continuous and large-scale extermination of meercats the operations can be carried out to advantage by units, or groups of eight natives, under the supervision of a trained European. The supervisor should be selected for his energy and reliability, as the whole scheme depends on the thoroughness with which the work is executed.

All the equipment necessary for such a unit comprises two gassing pumps, a supply of cyanide dust, a few spades, and about two hundred three-inch gin traps. Such a unit must, of course, be self-contained and mobile, i.e., provided with its own camping outfit and transport, so as to be on the spot the whole time and not to waste time going to and from their homes.

Naturally in all undertakings of this nature the cost involved should not be out of proportion to results obtained.

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From the summary of the work performed on the five infected farms, and the expenditure in eradicating the meercats, it is estimated that a party consisting of eight natives under the supervision of a trained European can clean an area of 1,000 morgen in four days, at an approximate cost of a little over £9.

For small-scale operations (e.g., for the farmer, who wishes to clean up his farm), the only equipment necessary would be one pump at £2. 15s.; say 2 dozen traps at 1s. 6d. each, and a small amount of Cyanogas. If the eradication is undertaken on a co-operative basis (several neighbouring farmers pooling together their equipment and labour) the cost can be brought down, well within the reach of every one.

D. DESTRUCTION OF MEERCATS WITH A VIEW TO THE ERADICATION OF RABIES.

Eradication of rabies in South Africa depends on the possibility of destroying the wild carnivora, which disseminate and propagate the disease amongst themselves.

It is fortunate perhaps, that the viverrids and particularly *Cynictis penicillata* seem to play the major rôle and that the infection discovered in other animals, until proved otherwise, may well be regarded as accidental.

Consequently a campaign of this sort must be directed mainly against the yellow mongoose. With this species should be included the suricate and ground-squirrel on account of their close association, commensal habits, and on account of the damage to crops done by the last.

Generalized extermination of these three species over the large area in which rabies occurs represents a formidable task; even if the work were undertaken voluntarily and co-operatively, or even under compulsion, by land-owners. It is doubtful whether anything more than a temporary reduction in the numbers of meercats would result from such an effort. The tremendous cost of organising, supervising, and maintaining such a scheme of total eradication, whether done by landowners themselves or by the State, would be prohibitive and out of all proportion to the losses due to the disease.

Before total eradication is resorted to, its effects on other animals, birds, and insects would have to be very carefully considered. It is possible that the "balance of nature" might be upset, resulting in a "plague" more harmful than rabies.

In a previous communication (Snyman and Thomas, 1939) it was shown that, although rabies occurs over a large part of the Union, yet it is restricted to more or less well-defined centres and localities, where it seems to smoulder for long periods and thence spread slowly.

This hypothesis is supported by the following observation:—

- (a) In glancing at the incidence map of rabies, one will notice that outbreaks are bunched together within a restricted area. The history of the outbreaks in these areas further supports this presumption.

- (b) In many centres the history of the outbreak shows that the disease had been smouldering for several years, e.g., on Trompsburg, Edenburg, and Vryburg town commonages.
- (c) At the farms Beestekraal and Philip in the Hoopstad District, and Sunnyside in the Bloemfontein District, rabid *Cynictis* were found in the same locality on the farms several months after the original outbreaks had been reported.
- (d) The number of meercat carcasses found on the infected farms, on which eradication was in progress, also would seem to indicate the presence of an epizootic amongst them.

If the hypothesis of the localized nature of the disease is correct, then eradication of rabies can be undertaken on a much reduced scale, involving only the actual centres of infection. For if all the infected animals, as well as all susceptible ones which might have been bitten, are destroyed, the disease at that point must die out, since it cannot persist outside the live animal. Should the area so cleansed of meercats become repopulated, it would be of no consequence provided the newcomers are not infected.

Success obviously depends on defining the area in which the destruction is to be carried out, and secondly on the thoroughness with which the destruction takes place.

The area in which such restricted destruction of meercats is to be carried out, depends on the extent to which the disease is believed to have spread in that locality.

Therefore a preliminary survey of the locality, becomes necessary, and when taken in conjunction with the history of the outbreak, the topography of the ground and a sound knowledge of the habits and habitation of meercats, one is enabled to determine the area in which the meercats have to be eradicated. In practice one can also judge the probable extent of the infection from the position and number of colonies, and the ease of contact between them. Such other portions of the adjoining ground are then also included according to local circumstances so that as wide a margin of safety is allowed consistent with the purpose in view, viz. to destroy all meercats likely to have been infected. On the other hand one should endeavour not to make the area unnecessarily large, as the increased cost may have an unfavourable effect on the issue.

Of great assistance, is the occurrence of carcasses of meercats, which have presumably died of rabies. The evidence of these constitutes a valuable guide in defining the centre of the infected area. When combing the area adjoining that regarded as infected, a keen look-out should be kept for the occurrence of such carcasses, and if they are found, the area to be treated should be extended accordingly.

Control measures should not only be directed towards the isolated outbreaks, but the ultimate aim should also be the total eradication of the disease from the country.

Such an ambitious aim is not entirely out of the question. For, if it is possible to eradicate or greatly to reduce the meercats, it follows that the disease will find it more and more difficult to persist and spread. Thus, by systematically destroying the carriers in the infected centres, by starting in the sparsely infected areas and gradually closing in on the central areas, the incidence of the disease will, it is hoped, be greatly reduced and in time even eradicated.

This is the scheme as envisaged, and as now being carried out, with a view to reduction and eventual eradication of rabies in the Union.

This does not mean, however, that other isolated or concerted efforts toward general destruction of meercats should not be contemplated, or should be abandoned if already started.

On the contrary, if farmers in a given district can be persuaded voluntarily to exterminate the meercats, so much the better; obviously rabies would have very little chance of persisting in such a district.

By every means at our disposal the general reduction of meercats should be encouraged, provided it is done in an economical way. There is, for instance, the system of premiums offered for captured vermin, which is worth a trial at any rate.

The Provincial Administration of the Orange Free State has as from 1st April, 1939, added *Cynictis penicillata* to the list of vermin, for whose destruction a reward is paid, on account of its pernicious habit of attacking newly born lambs. The reward of three pence per tail should be sufficient encouragement to reduce the number of these animals, as they are easily trapped. The response for the first three months has been very disappointing. Altogether rewards for only 2,720 tails, i.e. a total of £34 were claimed in the whole of the Province. Whereas at the price, trapping could be made quite a profitable "business".

It does not seem, therefore, that at this rate the encouragement given by the Provincial Administration will reduce the meercat numbers to such an extent as to have any noticeable effect on the incidence of rabies, because the eradication may be spasmodic on farms, and only undertaken, where the animals have acquired pernicious habits, and secondly no intensive campaign would be undertaken, unless farmers formed clubs on lines similar to those of the Jackal Clubs. Isolated undertakings in a small area, will, of course, only have a very transient effect on the meercat population at that point.

There are, however, weaknesses in the scheme outlined above to which consideration will have to be given.

In the first place outbreaks are not always noticed, or even reported, when they are known. One of the primary conditions on which the success of the scheme depends is thus rather uncertain, but susceptible to improvement by suitable propaganda.

Secondly this scheme depends on the assumption, that the yellow mongoose is the only source of infection. In the Vryburg district, where a large proportion of the outbreaks occurred in the genet, infection in them can hardly be regarded as accidental. Thus, even if the infection in meercats is completely destroyed, the genet may still be a source of reinfection for meercats. Here again it is hoped, that it will be possible to combat the disease in genets as well.

Apart from the obvious weaknesses above mentioned, it is fully realised, that the scheme is by no means foolproof and could easily go wrong at several points. That is why it has been insisted upon all along, that the eradication of meercats in rabies centres should not be left to the haphazard action of landowners, but should be undertaken by the State, and the work entrusted to a reliable staff specially trained for the purpose.

E.—OTHER CONTROL MEASURES AGAINST RABIES IN THE UNION.

Although constituting the main attack on the rabies problem in the Union, the proposed campaign against the carriers of this disease should not be regarded as the only weapon to be used. There are other measures, of more general nature, which should not be overlooked, e.g. :—

- (a) Prevention of fresh importation of rabies;
- (b) Quarantine and other State Veterinary measures against spread of the disease by domestic and other animals, especially dogs and cats.
- (c) And above all nation-wide propaganda, to—
 - (i) enlighten the public;
 - (ii) report all suspicious cases;
 - (iii) help destroy and keep down meercats;
 - (iv) and to collaborate with the State in all its measures to eradicate rabies.

(a) Prevention of fresh Importation of Rabies.

Although rabies is wide-spread and firmly established in some of our wild carnivora, it has the peculiarity, mentioned already, of not spreading in dogs. The outbreaks that have occurred in dogs, during the past twelve years, have been isolated cases, and in a few instances only did the infected dogs communicate the disease to members of their own species, or to other animals. It is therefore of the greatest importance, that the regulations imposed on the importation of dogs from neighbouring territories, and from overseas, should be rigidly enforced to prevent the introduction of a virus, which might behave differently when affecting dogs.

The provisions of the Stock Disease Act, No. 14 of 1911, aim mainly at total prohibition of the importation of dogs and cats from countries, where the disease is enzootic; and prescribe a period of six months quarantine for canines at Ports of Entry from other countries.

(b) Quarantine and Other State Veterinary Measures against Spread of the Disease by Domestic and Other Animals.

In 1936 the author described the legislation dealing with rabies, and the lines to be followed when outbreaks occur. Stress was laid on the special precautions to be taken when outbreaks, even in wild animals, occur near towns and villages, on account of the large dog population, to which the disease may be communicated in such places.

The usual precautions of restraining movements of dogs, isolating all suspected animals and destroying all stray animals and those, that have been bitten or have been in contact with infected animals, should be enforced.

These precautions, no matter how rigidly they be enforced, would not have the desired effect unless the source of the infection, which is usually the yellow mongoose, is not eradicated. On the contrary if dogs and cats are confined or destroyed, vermin and rodents will increase, thereby enhancing the propagation of rabies and possibly of bubonic plague also.

(c) Nation-wide Propaganda.

One of the first and most important steps to take against a disease of which the existence has been known for a short time only, and of which the epizootology is not understood by the public, is to enlighten them by all possible means as to dangers they run, how to protect themselves, and the duties they should perform.

This can be done by public lectures, addresses to farmers at association meetings, natural history lessons to school children by teachers, cinematographic representations, and by giving prominence to outbreaks in the press.

Two points should particularly be stressed, firstly to avoid being bitten by small wild carnivora. Special attention should be drawn to the fact, that a great many of the fatal cases in human beings have occurred in children, as a result of catching, what appeared to them to be tame meercats, but which were semi-paralysed animals in the last stages of rabies.

Secondly, people should be encouraged to report suspected cases of the disease, as success in eradicating by the methods at present at our disposal depends on an early recognition of all, or as many centres of infection as possible.

It should further be impressed on the public, that it is their duty to destroy and help keep down the numbers of meercats, and to collaborate with the State in all its measures to eradicate the disease.

SUMMARY.

A.—The study of the habits of meercats and their burrows has shown, (a) that the burrow is the most convenient place in which to destroy meercats, and (b) that those meercats, which escape contact with the gas in the burrows, together with those, that filter into an area on which destruction of meercats is taking place, may easily be destroyed by trapping.

B.—It is a practical proposition to exterminate *Cynictis penicillata*, the principle carrier of rabies, together with *Suricata suricatta* and *Geosciurus capensis* in an area, up to 10,000 morgen in extent, infected with rabies.

C.—A scheme has been evolved aiming at total eradication of rabies in the Union, by destroying the meercats in infected centres, first in the sparsely infected areas, and then by gradually closing in on the central infected areas.

D.—Success of the scheme depends on the thoroughness with which the eradication of meercats in the infected centres takes place; it should therefore, be undertaken by the State, and the work entrusted to a reliable staff, specially trained for the purpose.

ACKNOWLEDGMENTS.

In the first place, thanks are due to the Director of Veterinary Services for the funds, with which this work was carried out.

The valuable assistance rendered by Mr. J. Fourie, B.V.Sc., Government Veterinary Officer at Hoopstad, Mr. F. Kolbe, B.Sc., and Mr. L. Jordaan, both of the Zoological Survey staff, in carrying out the arduous and often unpleasant field work, is greatly appreciated.

I am grateful to Mr. Walker and Mr. Meyer, both of Onderstepoort, for the preparation of the illustrations accompanying this article.

I also wish to record thanks to Mr. E. H. Hendry of Messrs. African Explosives & Industries, Ltd., of S.A. for carrying out the tests with explosives, and to his Company for allowing him to do so.

Last but not least, I have to express special thanks to Dr. A. D. Thomas, Professor of Pathology at Onderstepoort, for his valuable help, advice and interest in connection with this work.

REFERENCES.

- ADMINISTRATOR'S NOTICE (1939). Regulations under the vermin destruction ordinance 1926, *Official Gazette of the Province of the Orange Free State* No. 12, 17th March, 1939, p. 217.
- AMICUS (1825). Over de Watervrees (Hydrophobia). *Het Nederduitsch Zuid-Afrikaansch Tydschrift*, Deel II. p. 435. Greig: Groenteplein, Kaapstad, 1825.
- ANON (1937).—La rage en Tchecoslovaquie Année 1936. *Bull. Off. Internat. Epiz.*, Vol. 14, p. 359.
- ANON (1937). La rage en Yougoslavie Année 1936. *Bull. Off. Internat. Epiz.*, Vol. 14, p. 360.
- BAKER, J. N., McALPINE, J. C. AND DAWLING, J. D. (1936). Rabies: A continuing challenge. *Sth. Med. Jnl.*, Vol. 29, pp. 547-557.
- BALAZET, L. (1939). Etat actuel de nos connaissances sur la rage dans les contrées tropicales et sub-tropicales et x prophylaxie. La vaccination preventive des chiens. *Office International des Epizooties*, Vol. XVII, No. 4, pp. 786-790.

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- BARROW, JOHN (1801). An account of Travels into the Interior of S.A. Vol. 1, p. 231. T. Cadell Jun. and W. Davies in Strand, 1801.
- BARRY, W. C. (1934). *Report of the Livestock Division, Rep. Dept. Agric. New Zealand*, pp. 13-20.
- BIGALKE, R. (1921). The Ground Squirrel—*Geosciurus capensis* Kerr. *Jnl. of Dept. of Agric.*, Nov., 1921 and Feb., 1922.
- BIGALKE, R. (1934). A biological Survey of the Union of S.A. *Jnl. of Science*, Vol. XXI, p. 396.
- CAMERON, A. G. (1933). Report of the Contagious Diseases Division, Health of Animals Branch, year ending 31st March, 1933. *Report. Vet. Direct. Gen.*, Canada, 1932-1933, pp. 12-18.
- CONFERENCE on Co-ordination of Veterinary Research held at Kabeta 6-10 Jan. 1934. *Conference of Governors of British East African Territories*, pp. 80.
- CHAPMAN, JAMES (1868). Travels in the Interior of South Africa. Vol. 1, p. 453. Bell & Dadd, York Street, London.
- CLUVER, EUSTACE (1927). Rabies in S.A. *J. of Med. Ass. of S.A.*, Vol. 1, No. 9, p. 247.
- CRAWFORD, M. (1934). *Administration Report of the Govt. Surgeon for 1933*, Ceylon, p. 21. Columbo Govt. Press.
- DIRECTOR OF VETERINARY SERVICES, Depart. of Agriculture. *File V. 288/1/1. File V. 288/2/1.*
- DU TOIT, P. J. (1929). Rabies in S.A. *Pan African Agric. and Vet. Congress*, Aug. 1929, pp. 272-284.
- DU TOIT, P. J. (1936). Wild carnivora as carriers of Rabies. *Quat. Bull. Health Org.*, V, p. 162.
- EDWARDS, MORGAN (1939). Rabies not absent in Venezuela. *Vet. Record*, Vol. 51 (5), p. 156.
- ELLIOT, R. C. (1925). South African Law on Stock Diseases. Juta & Co., Ltd., Cape Town.
- FITZSIMONS, F. W. (1919). Natural History of South Africa. *Mammals*, Vol. II, p. 7. Longmans, Green & Co., London.
- FORDER, GEORGE (1885). Importation of dogs from Mauritius. *Natal Archives*, C. 50/1818/1805.
- FOURIE, L. (1936). Field work against Plague. *Proceedings of the Transvaal Mine Medical Officers Association*. Vol. XV, No. 171, page 43.
- GIESE, C., AND ZUNKER (1935). Les possibilités actuelles de la prophylaxie de la rage. *Bull. Off. Internat. Epiz.*, Vol. 10, pp. 53-66.
- GOODALL, A. G. (1929). Rabies in Wolmaransstad District. *Director of Veterinary Services Dept. of Agric.*, *File V. 288/1/1.*
- GOVERNMENT VETERINARY OFFICER, Mafeking. *File 6/4/1-6.*
- GRAY, C. E. (1903). *Veterinary Report for the year ending 31st March, 1903. Report of the Dept. of Agric.*, Southern Rhodesia, p. 18.
- GRAY, C. E. (1905). *Veterinary Report for the year ending 31st March, 1905. Report of the Dept. of Agric.*, Southern Rhodesia, p. 21.
- HAAGNER, A. (1920). South African Mammals. Witherby Iandow.
- HAGAN, W. A. (1934). *Report of the New York State Vet. College at Cornell University, 1932-1933.*

- HENRY, M. (1936). Livestock Division. Report No. 12. *Recording Control work during the Year ended 30th June, 1936. Report Dept. Agric., New Zealand*, pp. 6-24.
- HERZENBERG, L. (1928). Two cases of Hydrophobia. *J. Med. Ass. S.A.*, Vol. 2, No. 23, p. 659.
- HORNBY, H. G. (1932). *Annual Report of the Department of Vet. Science and Animal Husbandry, 1933. Tanganyika.*
- HOBDAV, J. H. N. (1936). *Veterinary Report for 1936. Bechuanaland Protectorate*, p. 37.
- HUTCHEON, D. (1894). *Reports of the Colonial Veterinary Surgeon for the year 1893. Cape of Good Hope, Dept. of Agric.*, pp. 7-10.
- HUTYRA, FRANS AND MAREK, JOSEF (1922). Special Pathology and Therapeutics of the Diseases of Domestic Animals. Vol. 1, p. 464. Publ. Alexander Eger, Chicago.
- HYDROPHOBIA—Narrow Escape. Report in *The Friend of the Free State*, Vol. XII, No. 617, p. 1861.
- KANDO, S. (1934). Rabies and its control in Japan. *Proc. 5th Pacific Sci. Congr., Canada 1933*, pp. 3055-3060.
- KENEDY, W. (1934). *Annual Report of Veterinary Services Sudan Government, 1933.*
- KRAUS, R., GERLACH, F. AND SCHEINBERG, F. (1926). *Lyssa bei Mensch Und Tier. Urban & Schwarzenberg, Friedrichstrasse, Berlin.*
- LEWIS, A. (1926). Rainfall Normals. *Report of the Director of Irrigation. Union of South Africa, 1926.*
- LEWIS, A. (1929). *Annual Report of the Director of Irrigation. (Met. 43) 1928. Union of South Africa.*
- LEWIS, A. (1930). *Annual Report of the Director of Irrigation. (Met. 43) 1929. Union of S.A.*
- LEWIS, A. (1931). *Annual Report of the Director of Irrigation. (Met. 43) 1930. Union of S.A.*
- LEWIS, A. (1933). *Annual Report of the Director of Irrigation for the years 1931 and 1932. Union of South Africa.*
- LEWIS, A. (1935). *Report of the Director of Irrigation for the years 1933 and 1934. Union of S.A.*
- LEWIS, A. (1936). *Report of the Director of Irrigation 1935-1936, Union of South Africa.*
- LEWIS, A. (1938). *Report of the Director of Irrigation. (M. 43) for the year 1937, Union of South Africa.*
- LIVINGSTONE, DAVID (1857). *Missionary Travels and Researches in S.A.* p. 127. John Murray, Albermarle St., London.
- MARAIS, I. P. AND NEITZ, W. O. (1932). Rabies as it occurs in S.A. *18th Report of the Dir. of Vet. Serv., I*, pp. 7-98.
- METIVIER, H. V. M. (1937). *Report of the Vet. Division, 1936. Adm. Rpt. Dir. Agric., Trinidad & Tabago, 1936*, pp. 49-52.
- METIVIER, H. V. M. (1935). Paralytic Rabies in livestock. *Jnl. of Comp. Path. and Ther.*, Vol. XLVIII, Part 4, Dec. 1935, p. 245.
- MITCHELL, D. T. (1930). Rabies in Burma. *Proc. Pan-African Agric. & Vet. Conf. Pretoria, Aug., 1929*, p. 284.
- MITCHELL, J. A. (1929). *Annual Report of the Dept of Public Health, year ended 30th June, 1929*, p.36.

STUDY AND CONTROL OF THE VECTORS OF RABIES.

- MITCHELL, J. A. (1930). *Annual Report of the Dept. of Public Health*, year ended 30th June, 1930, p. 40.
- MITCHELL, J. A. (1931). *Annual Report of the Dept. of Public Health*, year ended 30th June, 1931, p. 41.
- MITCHELL, J. ALEXANDER (1929). Rabies. *Annual Reports of the Department of Public Health, Union of S.A.*, year ended 30th June, 1929, p. 41.
- MURIE, OLOUS J. (1935). Food habits of the coyote in the Jackson Hall Wyo. *Circ. No. 362, U.S.A. Agric.*
- NAUDE, T. J. (1934). Termites in relation to Veld-destruction and erosion. *Union of S.A. Dept. of Agric., Bull. No. 184.*
- NEITZ, W. O. (1937). Rabies in South Africa. *Farming in S.A.*, Vol. XII No. 132, p. 130-133.
- NEITZ, W. O. & THOMAS, A.D. (1939). Rabies in S.A. Occurrence and distribution of cases, 1932. *Onderstepoort Jnl.*, Vol. I, No. 1, pp. 51-55.
- NEITZ, W. O. and THOMAS, A. D. (1934). Rabies in South Africa, occurrence and cases in 1933. *Onderstepoort Jnl.*, Vol. 3, No. 2, p. 335.
- NICOLAU, S., MATHIS, C AND CONSTANTINESCO VAL (1934). La Rage autochtone (Maladie au chien fou) en Afrique Occidentale Francaise. *Ann. Inst. Pasteur*, Vol. 50, p. 778.
- PAWAW, J. L. (1936). The Transmission of Paralytic Rabies in Trinidad by the Vampire Bat. *Annals of Tropical Medicine and Parasitology*, Vol. 30, No. 1, page 122.
- PAWAW, J. L. (1936). Rabies in Vampire Bat of Trinidad. *Ann. Trop. Med. Parasit.*, Vol. 30, pp. 401-422.
- PRISSOU, H. (1930). Veterinary Legislation in Madagascar. *Proc. Pan-African Agric. & Vet. Conf. Pretoria, Aug., 1929*, p. 195.
- PRISSOU, H. (1930). Veterinary Services in the Cameroon. *Proc. Pan-African Agric. & Vet. Conf. Pretoria, Aug., 1929*, p. 188.
- PRITCHETT, H. D. (19.....). Rabies in two squirrels. *Am. Vet. Med. Jnl.*, Vol. 92, No. 4, p. 563.
- PRITCHETT, H. D. (1938). *Rage Statistiques, Office International des Epizooties*, Vol. 7, Nos. 1-6.
- RECORDS, E. (1934). *Biennial Report of the State Rabies Commission for period July, 1932, to June, 1930.* Carson City.
- RINEHART, H. C., BREED, F., AND BARNES, M. F. (1938). Report of the Committee on Rabies. *J. Am. Vet. Med. Ass.*, Vol. 2, No. 3, p. 307.
- ROBERTS, AUSTEN (1935). Mammals concerned in Bubonic Plaque and Rabies problems of South Africa. *S.A. Jnl. of Science.* Vol. XXXII, pp. 414-460.
- SCHEFFER, THEO H. (1931). Habits and economic status of the Pocket Gophers. *U.S.A. Dept. Agric. Tech. Bull.*, No. 224.
- SCHUMANN, T. E. W. AND THOMPSON, W. R. (1934). A Study of S.A. Rainfall, Secular Variations and Agricultural Aspects. *Univ. of Pretoria, Series I*, No. 28, pp. 1-15.
- SCLATER (1900). The Fauna of South Africa. *Mammals*, Vol. I. P. H. Porter, Princes Street, London.
- SENIOR VETERINARY OFFICER, Cape Town. *File 13/14A.*

- SENIOR VETERINARY OFFICER, Bloemfontein. *Files B. 80, 12/1/1 to 12/27/14.*
- SENIOR VETERINARY OFFICER, Windhoek. *Files VI/14 and V. 2/55.*
- SINCLAIR, J. M. (1906). *Report of the Chief Veterinary Surgeon for the year ending 31st March, 1906. Report of Dept. of Agric., Salisbury, p. 18.*
- SINCLAIR, J. M. (1908). *Report of the Chief Veterinary Surgeon, year ending 31st December, 1907. Report of Dept. of Agric., Salisbury, p. 22.*
- SINCLAIR, J. M. (1909). *Report of the Chief Veterinary Surgeon year ending 31st December, 1909. Report of the Dept. of Agric., Salisbury, p. 29.*
- SINCLAIR, J. M. (1911). *Report of the Chief Veterinary Surgeon year ending 31st December, 1910. Report of the Dept. of Agric., Salisbury, p. 37.*
- SINCLAIR, J. M. (1912). *Report of the Chief Veterinary Surgeon year ending 31st December, 1912. Report of the Dept. of Agric., Salisbury, p. 6.*
- SINCLAIR, J. M. (1914). *Report of the Chief Veterinary Surgeon, year ending 31st March, 1913. Report of the Dept. of Agric., Salisbury, p. 5.*
- SHORT, P. G. (1933). *Annual Report of the Veterinary Dept. for the year 1932. Federated Malay States. Federated Malay States Govt. Gaz. Suppl., June 11th, 1932, p. 9.*
- SHORTRIDGE, G. C. (1934). *The Mammals of South West Africa. William Hinemann, London.*
- SMITH, J. (1930). *Dept. of Animal Health. Govt. of Northern Rhodesia. Annual Report, 1929.*
- SMITH, J. (1931). *Dept. of Animal Health. Govt. of Northern Rhodesia. Annual Report, 1930.*
- SMITH, J. (1932). *Dept. of Animal Health. Govt. of Northern Rhodesia. Annual Report, 1931.*
- SMITH, J. (1933). *Dept. of Animal Health. Govt. of Northern Rhodesia. Annual Report, 1932.*
- SMITH, J. (1934). *Dept. of Animal Health. Govt. of Northern Rhodesia. Annual Report, 1933.*
- SMITH, J. (1935). *Dept. of Animal Health. Govt. of Northern Rhodesia. Annual Report, 1934.*
- SMITH, J. M. (1937). *Report of the Chief Veterinary Officer, year ending March, 1936. Palestine. Report Vet. Serv. Dept., 1935-1936.*
- SNYMAN, P. S. (1937). *Rabies in S.A. Jnl. S.A.V.M.A., Vol. VIII, No. 3, pp. 126-133.*
- SNYMAN, P., AND THOMAS, A. D. (1939). *The Carriers of Rabies in South Africa. Acta Conventus Tertii de Tropicis Atque Malariae Mortis. Part I, p. 616: Spin en Zoon. Amsterdam.*
- STANHOPE, R. A. (1928). *Rabies in Malaya. The Vet. Record, Vol. 8, No. 47, pp. 999-1004.*
- STANHOPE, R. A. B. (1928). *Rabies in Malaya. Vet. Jnl., Vol. 8, No 47, p. 999.*
- STEEDMAN, ANDREW (1835). *Wanderings and Adventure in the Interior of Southern Africa. Vol. II, p. 96. Longmans & Co., Paternoster Row, London*

STUDY AND CONTROL OF THE VECTORS OF RABIES.

- STEYN, D. G. (1939). The Sensitivity of the Picrate Paper Test (Guignard Test) for Hydrocyanic Acid. *J. S.A.V.M.A.*, Vol. X, No. 2, pp. 65-68.
- THEILER, A. (1934). Rabies in South Africa. *Vet. Journal*, Vol. 90, pp. 9-13.
- THOMAS, A. D. (1936). Destruction of Rabies Carriers. *Farming in S.A.*, Nov., 1936.
- THOMAS, A. D. AND NEITZ, W. O. (1933). The Importance of Diseases in Wild Animals. *S.A. Jnl. of Science*, Vol. XXX, pp. 419-425.
- THOMAS, A. D., AND NEITZ, W. O. (1936). Wild Carnivora as Carriers of Rabies. *Jnl. of Royal Sanitary Inst.* LVI No. 12, p. 754.
- THUNBERG, CHARLES PETER (1780). Travels in Europe, Africa and Asia between the years 1770-1779, Vol. I, p. 172. F. & C. Rivington, No. 62, St. Paul's Churchyard, London.
- WILLIAMS, H. B. *Annual Report of the Sudan Vet. Service*, 1936. Sudan Govt., 1937.
- WILTSHIRE, S. (1894). *Natal Departmental Reports*, Natal Archives, p. H.53.

Psittacosis in Domestic Pigeons.

By J. D. W. A. COLES, Section of Poultry, Onderstepoort.

It may perhaps be taken for granted that all members of the order, Psittaciformes, are susceptible to psittacosis. Within the order are parrots, macaws, conures, corellas, quarriors, cockatoos, parrotlets, cockateels, paroquets and parrakeets. The budgerigar or lovebird (*Melopsittacus undulatus*) is the shell parrakeet and, of course, is often the source of human infections.

Most public health regulations of the present day are designed to counter the dangers associated with the Psittaciformes, and it is not widely recognised that avian species without this order can, on occasion, be a menace to man.

In 1933, Meyer and Eddie isolated a relatively weak strain of the virus from apparently healthy canaries (*Serinus canarius*), that were associated with two human cases of psittacosis in one household. About the same time these authors inspected an aviary and found a listless butterfly finch (*Cyanospiza ciris*), which had a distended abdomen, its plumage ruffled and its tail soiled with faeces. The virus was not detected by microscopic examination of material from the finch, but the intraperitoneal injection of a liver and spleen emulsion killed test mice in ten days with typical psittacosis.

Meyer afterwards demonstrated that the Java rice bird (*Padda oryzivora*) could become infected naturally. He also showed the Pekin robin (*Liothrix luteus*) and the bullfinch (*Pyrrhula vulgaris*) to be susceptible.

In 1938, Haagen and Mauer in Germany recorded the presence of psittacosis virus in imported finches and in indigenous siskins (*Spinus spinus*?) and coal tits (*Parus ater*?); these were all natural infections. In the same year the same authors proved that the fulmar petrel (*Fulmarus glacialis*) was responsible for the disease in man in the Faroe Islands.

Gradually it is being realised that no avian species can be regarded as harmless, unless exhaustive experiments have proved it to be insusceptible. Even the domestic chicken can be infected artificially.

So far as we are aware, psittacosis has never been diagnosed in the domestic pigeon (*Columba livia* var. *domestica*) and a recent outbreak forms the subject of this paper.

In March 1939 a big pigeon breeder in Johannesburg, Transvaal, sent two young fancy domestic pigeons for examination. Both birds were dead on arrival. The owner stated he had about 200 pigeons and that a few of them were ailing. One of the birds, that died before it was sent, had been ill only four days; the symptoms were listlessness and lack of appetite. The other had been off colour two or three weeks, and had moped and shown no interest in food.

We examined the carcasses superficially, and noted that the vent feathers were soiled with diarrhoeic faeces. Veterinary students were then told to perform the autopsies, and they were warned to be careful and not infect their eyes and mouths, as it was possible that the deaths were due to salmonellosis. The first pigeon had a liver twice the normal size and the organ was diffusely yellowish in parts; there was pronounced intestinal catarrh; no other obvious lesions were detected. The second pigeon was rather decomposed; the liver was slightly swollen; there was marked catarrh of the intestines; a moderate degree of aerocystitis characterised the left abdominal air sac. Heart blood from each bird was seeded in brilliant green bouillon and on brilliant green agar slants—no bacterial growth occurred.

Smears of the heart blood, lungs and spleen were stained with Giemsa. The students were dismissed. An hour later, the lung and spleen smears of the first pigeon were found to contain rather numerous colonies of psittacosis virus; the organisms were relatively infrequent in the spleen and liver of the second. As was to be expected, the virus particles showed a marked predilection for macrophages.

The viscera of the birds were retrieved and an emulsion of the lungs of both pigeons was inoculated intraperitoneally into 6 white mice. Five of the mice died of bacterial septicaemia within 2 days. On the fifth day the remaining mouse died of typical psittacosis and the L.C.L. bodies were seen in fairly large numbers in the macrophages of the peritoneal exudate.

A spleen and liver emulsion of this mouse was injected intraperitoneally into 6 more mice. Owing to the danger of spreading the infection in unsuitable rooms, these mice were sacrificed 5 to 7 days afterwards, and the parasites were demonstrated in the spleens and peritoneal exudates of all.

A visit was paid to the infected premises. The aviaries were beyond reproach and no sick pigeons were observed. The only other bird present was an apparently healthy budgerigar, and it was in contact with the pigeons. No legal authority existed for dealing with the outbreak, and the owner was not disposed in any way to worry about it. As a result, we were unable to examine even the lovebird to see if it was a carrier.

Although four students, two assistants and the author had been exposed to considerable risk of infection, none of them subsequently developed any signs of illness.

In February 1940, another young pigeon was received from the same breeder. It died just after it arrived and the vent feathers

were soiled with liquid faeces. Adequate precautions were taken to prevent human infection. There was a yellow diphtheritic pseudo-membrane on the back of the tongue, due to *Trichomonas hepatica*. The wall of the left abdominal air sac was thickened and turbid. The liver was slightly swollen and there was a marked pseudo-membranous perihepatitis, but no trichomonads or bacteria could be found in smears made from the surface of the liver. The spleen was a little enlarged and light pink in colour, and a prolonged search revealed four macrophages containing psittacosis granules. A blood smear showed a few *Haemoproteus columbae*. Six white mice were inoculated intraperitoneally with an emulsion of the heart, lungs, spleen and liver; unfortunately, all died within a day as a result of a *Salmonella typhimurium* infection, the presence of which had not been suspected when the bird was autopsied. Brilliant green agar slants seeded with the heart blood of the pigeon, showed colonies of *S. typhimurium* in 24 hours. This pigeon undoubtedly died of salmonellosis. It was infected also with *Trichomonas hepatica*, *Haemoproteus columbae* and the virus of psittacosis. Unfortunately, the presence of the last named could not be confirmed by mouse inoculation.

The owner was requested to send two more pigeons. These soon arrived, and were young. One was dead and slightly decomposed. The vent feathers were soiled because of diarrhoea; the lungs were oedematous, and the liver and spleen swollen; spleen and liver smears were full of pigment, due to the breaking down of numerous *H. columbae*. *S. typhimurium* was isolated from the heart blood. Six white mice were inoculated intraperitoneally with an emulsion of liver, spleen and lung, but all died within 5 days of a bacterial peritonitis and septicaemia.

The living pigeon was rather weak and emaciated and had diarrhoea. It was killed. Nothing special was to be observed at autopsy, except a few cheesy lesions in the mouth due to *T. hepatica*. *H. columbae* appeared infrequently in the red cells, and a blood culture yielded a few colonies of *S. typhimurium*. An emulsion of liver, spleen and lung was injected intraperitoneally into 6 white mice and two died of peritonitis within 3 days. The other four mice lived and were sacrificed after 12 days, as they looked healthy. All four had rather swollen spleens and slight ascites. One animal had leucaemia. The virus of psittacosis was easily found in macrophages in a smear of the liver surface of one mouse; in a second mouse the parasites were rare; in the remaining two mice no organisms could be seen.

Thus, these last two pigeons again showed *T. hepatica*, *H. columbae* and *S. typhimurium* infections. In one of them, the presence of psittacosis was confirmed by mouse inoculation, although the organisms were not shown microscopically in the bird itself. The deaths were undoubtedly due, mainly if not entirely, to paratyphoid.

These experiences are reported at length, because they illustrate most clearly the difficulties that may be encountered when an attempt is made to diagnose psittacosis, particularly the latent form. One

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should not be deterred or defeated by the presence of salmonellosis; in such cases mice should be injected with material from birds that have only just sickened for, in them, the *Salmonellas* will probably be too few to kill a mouse. Theoretically, it is possible to separate the *Salmonellas* from the L.C.L. bodies by filtration or centrifugation, but this is hardly likely to be successful when the latter are rare. Another complicating factor when we consider filtration and centrifugation is the relative weakness of many psittacosis strains for mice; we cannot afford to lose any of the little virus present by these processes. Strains from Australian birds are usually of comparatively low pathogenicity, and the new Johannesburg pigeon strain seems to be the same.

It is not unusual for paratyphoid fever to complicate psittacosis infections in avians. Nocard in 1893 isolated a Gram-negative bacterium from a bird with parrot-fever, and called it *Bacillus psittacosis*. It now seems certain that this organism was really *S. typhimurium*. Meyer and Eddie reported that salmonellosis is not infrequently found in shipments of South American birds, and they diagnosed dual infections of paratyphoid and psittacosis in some paroquets. The great majority of these avian *Salmonellas* are IV variants of *S. typhimurium*, i.e. *S. typhimurium* var. *Copenhagen*.

SUMMARY.

Psittacosis has been found in fancy domestic pigeons in South Africa. This is the first record of the disease here, and probably the first of its presence in pigeons. The diagnosis was confirmed by mouse inoculation. The virus seems to resemble most Australian strains, in that it is not highly virulent for mice.

Some of the pigeons were also suffering from *S. typhimurium*, *H. columbae* and *T. hepatica* infections.

Psittacosis apparently has not occurred in the owner of the pigeons, or in his family and servants. Seven students and laboratory workers remained healthy, although exposed for about two hours to the infection while the first birds were being autopsied.

ACKNOWLEDGMENT.

The writer wishes to thank Mr. T. Meyer of this institute for preparing the photomicrographs of the organisms in the pigeons.

ADDENDUM.

At the end of 1940 the owner of the pigeons consented to their destruction and 282 were killed. Only two looked sick—due to sporadic diseases. Spleens were collected in 50 per cent. glycerine from a third of the birds, ten being put in each bottle. Next morning six white mice were injected intraperitoneally with a mixture of the mushed spleens in each bottle. A few died of intercurrent diseases during the following three weeks, but in no instance was psittacosis diagnosed. The survivors were then killed for the inoculation of a second generation of mice. Again it was impossible to set up

psittacosis. Besides the pigeons and a few bantams kept well away from them, no avians were on the premises. These results suggest that psittacosis does not easily spread from one pigeon to another.

REFERENCES.

- GEIGER, J. C., CROWLEY, A. B., MEYER, K. F., AND EDDIE, B. U. (1939). Administrative Problems in Connection with Psittacosis and the Importation of Australian Parrots. *Jnl. Amer. Med. As.*, Vol. 113, pp. 1479-81.
- HAAGEN, E., AND MAUER, G. (1938). Die Psittakose. *Deuts. Med. Wschr.*, 64 Jahrgang I, pp. 568-71.
- HAAGEN, E., AND MAUER, G. (1938). Ueber eine auf den Menschen übertragbare Viruskrankeheit bei Sturmvögeln und ihre Beziehung zur Psittakose. *Zent. f. Bakt., Parasitenk., u. Infekt., Abt. I Orig.*, Vol. 143, pp. 81-88.
- LAZARUS, A. S., AND MEYER, K. F. (1939). The Virus of Psittacosis. I. Propagation and Development Cycle in the Egg Membrane, Purification and Concentration. *Jnl. Bact.*, Vol. 38, pp. 121-51.
- MEYER, K. F. (1935). Psittacosis. *Proc. Twelfth Internat. Vet. Congress*, Vol. 3, pp. 182-205.
- MEYER, K. F., AND EDDIE, B. (1933). Spontaneous Psittacosis Infections of the Canary and Butterfly Finch. *Proc. Soc. Exp. Biol. and Med.*, Vol. 30, pp. 481-2.
- MEYER, K. F., AND EDDIE, B. (1933). Latent Psittacosis Infections in Shell Parrakeets. *Proc. Soc. Exp. Biol. and Med.*, Vol. 30, pp. 484-8.
- MEYER, K. F., AND EDDIE, B. (1934). Psittacosis in the Native Australian Budgerigars. *Proc. Soc. Exp. Biol. and Med.*, Vol. 31, pp. 917-20.
- MEYER, K. F., AND EDDIE, B. (1939). Psittacosis in Importations of Psittacine Birds from the South American and Australian Continent. *Jnl. Infect. Dis.*, Vol. 65, pp. 234-41.

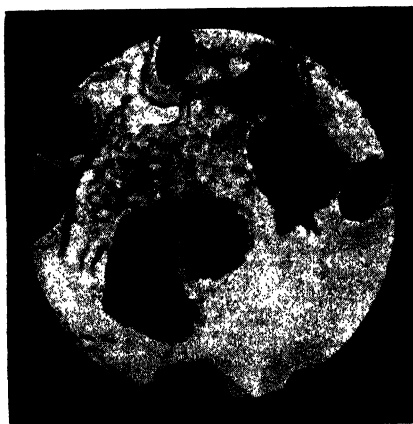


Fig. 1.—1400 \times . Pigeon. Lung smear. Vacuolated macrophage containing a large colony of Levinthal-Coles-Lillie bodies to the right of the nucleus, and a smaller colony above the nucleus. To the right of and above this cell, is another cell parasitized mainly with initial bodies.

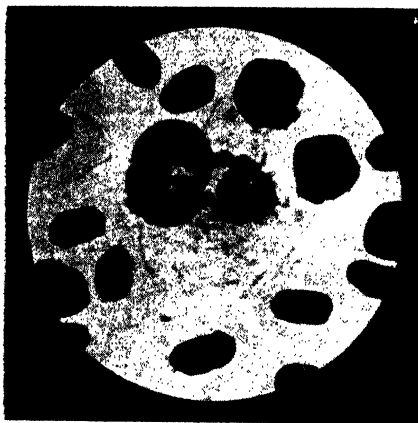


Fig. 2.—1400 x. Pigeon. Lung smear. Macrophage containing a colony of elementary bodies to the right of the nucleus.

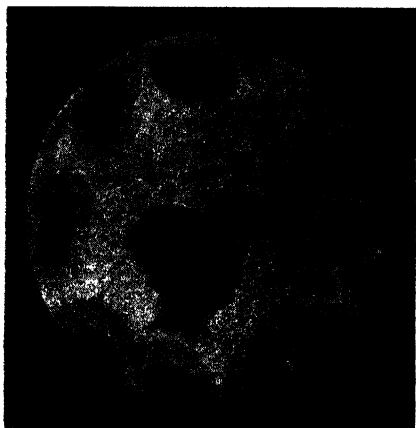


Fig. 3.—1400 x. Pigeon. Lung smear. Macrophage harbouring a colony of *Rickettsia psittaci*.

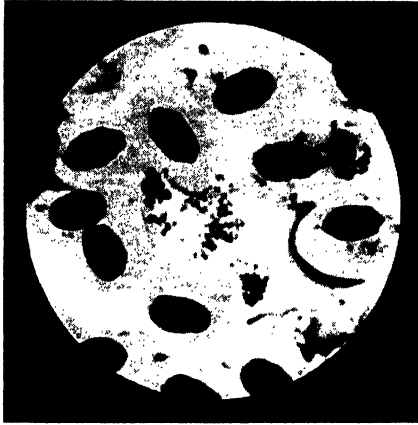


Fig. 4.—1400 x. Pigeon. Lung smear. A group of initial and elementary bodies lying scattered between erythrocytes.

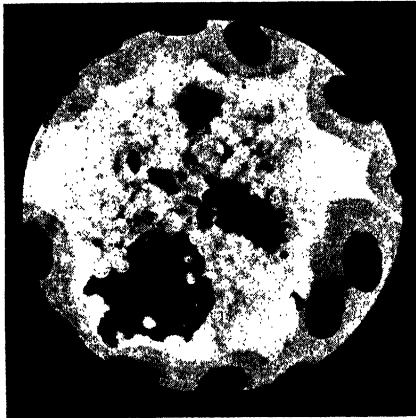


Fig. 5.—1400 x. Pigeon. Lung smear. Macrophage with elementary bodies in the cytoplasm.

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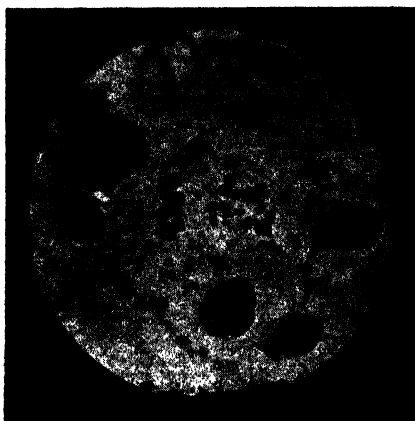


Fig. 6.—1400 x. Pigeon. Lung smear. A free-lying group of initial and elementary bodies.

All smears were strained with Giemsa.

Lillie called the parasites, *Rickettsia psittaci*, in 1930. In the same year Levinthal proposed the name, *Microbacterium multifforme psittacosis*. Most authors usually refer to the organisms as L.C.L. bodies, or Levinthal-Coles-Lillie bodies. The elementary bodies are the small particles of the virus, that stain like chromatin. Initial bodies are the larger virus particles, that stain light blue with Giemsa.

The Susceptibility of Cattle to the Virus of Bluetongue.

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INTRODUCTION.

In another article we (Mason and Neitz, 1940) recorded the results of investigating a disease of cattle, erosive stomatitis. We showed that the cause was a filterable virus which was not that of bluetongue. In the course of this work we, and a number of our colleagues, were struck by the similarity of lesions produced by us to some produced by Bekker, de Kock and Quinlan (1934) with bluetongue virus isolated from cattle. According to these workers, the bluetongue virus produced, under experimental conditions, an elevation in temperature, obvious illness, and erosion and hyperaemia of the buccal mucous membrane in cattle. In bovines naturally infected in the field extensive mouth lesions, and skin and foot lesions were also seen.

In our article we showed that we could not isolate bluetongue virus from the local lesions or the blood of cattle artificially infected with erosive stomatitis. However, we considered that the question of the susceptibility of cattle to bluetongue, particularly the production of mouth lesions was so important that further investigation was called for. It will save repetition if it is now stated that the expression "no reaction", unqualified, means no reaction of any kind, thermal, constitutional, or local. All but three of the calves used were bred at Onderstepoort under tick-free conditions; the exceptions were calves reared at the farm Kaalplaas under veld conditions. The virus used was one of those isolated from cattle by Bekker *et al.*, and had been passaged serially 14 times through sheep.

EXPERIMENTS.

Experiment 1.—This is summarized in Table 1. The calves used, 7697 and 7595, were bred at Onderstepoort.

SUSCEPTIBILITY OF CATTLE TO BLUETONGUE.

TABLE 1.

Attempts to Infect Calves with Bluetongue Virus by Scarification, Intranasal Injection, and Subcutaneous Injection.

Animal.	Treatment.	Result.	Remarks.
C. 7697....	30/8/39. Scarified tongue, dental pad, and lower lip. Virus (blood, sh. 55116) applied	No reaction up to 18/9/39	Tiny white pimple on pad on 6th day; disappeared on 10th day.
C. 7697....	7/10/39, 10 c.c. virus (blood sh. 55875) into each nostril	No reaction up to 18/10/39	—
Sh. 55913..	18/10/39, 5 c.c., s.c. blood of calf 7697	No reaction.....	6/11/39, tested for immunity. Reacted (B.T.), and recovered.
C. 7697....	15/11/39, 5 c.c. virus i.v. (blood, sh. 55913)	No reaction up to 30/11/39	—
Sh. 56544..	30/11/39, 5 c.c., s.c. blood, calf 7697	Reacted (B.T.) and recovered	—
C. 7595....	30/8/39, scarified tongue, dental pad and lower lip. Saline applied (control to C. 7697)	No reaction up to 18/9/39	—
C. 7595....	7/10/39, scarified tongue, dental pad and lower lip. Virus (blood sh. 55875) applied	No reaction up to 15/11/39	—
C. 7595....	15/11/39, 5 c.c. virus s.c. (blood sh. 55913)	No reaction up to 7/12/39	—
Sh. 56545..	30/11/39, 5 c.c., s.c. blood, calf 7595	Reacted (B.T.) and recovered	—

(C. = calf; sh. = sheep; s.c. = subcutaneously; i.v. = intravenously).

The results show that known infective blood produced no symptoms or lesions in calves when injected by scarification or by the intranasal, subcutaneous, or intravenous routes. Calf 7697 did not become inapparently infected by the intranasal injection of virus (see negative transmission to sheep 55913) but both calves did become inapparently infected when the virus was given subcutaneously or intravenously (see positive transmission to sheep 56544 and 56545). The tiny white elevation that appeared on the lip of calf 7697 was almost certainly a healing portion of the scarification wound.

Experiment 2.—Calf 7585 (Kaalplaas) was inoculated intralingually in 2 places with virus (blood, sheep 52759) which was also rubbed into the scarified dental pad and lower lip. No reaction attributable to bluetongue virus occurred during the observation period of 24 days. On the 4th day a few, very small, very superficial erosions appeared on the scarification wounds; there is no doubt that these were of traumatic origin.

Experiment 3.—Two Onderstepoort calves, 7468 and 7700, and one Kaalplaas calf, 7494, each received 20 cc. of virus (blood, sheep 52697) intravenously and in addition received the same virus on

scarified portions of the tongue, dental pad, and lower lip. No reaction of any kind occurred during the observation period of 30 days. Sub-inoculations into sheep were carried out with the blood of calf 7468. Sheep 53696 received 5 cc. of blood 15 days after the attempted infection of calf 7468 and sheep 52667, 10 cc. intravenously 29 days after; neither reacted and both were later shown to be susceptible to bluetongue.

Not one of the 3 calves became visibly infected, and, in addition, it would appear that calf 7468 did not become inapparently infected. This failure cannot be attributed to the lack of infectivity of the blood of the donor, sheep 52697. Calf 7543 (Experiment 4) received some of the same blood on the same day as calves 7468, 7700 and 7494 and became inapparently infected.

Experiment 4.—An Onderstepoort calf 7543 received 10 cc. of the blood of sheep 52697 intravenously and the same blood was applied to scarifications on the tongue, dental pad, and lower lip.

No reaction of any kind occurred until the 15th day. At this time, roughly circular, very superficial erosions about 0.75 cm. in diameter were observed on each side of the lower lip. The erosions looked as if they had been punched out. The base was slightly redder than the normal mucous membrane. Salivation although increased was not excessive. Scrapings were removed from the erosions and held in phosphate buffer of pH 7.4, and formed the inoculum for another experiment to be noted later. The erosions healed in 5 days. No other reaction occurred during the next 15 days. The subinoculations carried out are recorded in Table 2.

TABLE 2.

Subinoculations carried out from Calf 7543 of Experiment 4 (inoculated 9.2.39).

Animal.	Date.	Inoculum.	Result.	Immunity Test.
Sh. 53713	20/2/39	Blood: 5 c.c., s.c.....	Reaction....	31/3/39. No reaction.
Sh. 53686	20/2/39	Blood: 5 c.c., s.c.....	Reaction† B.T.	—
Sh. 53614	24/2/39	Erosion scrapings, i.v....	Reaction....	23/3/39. No reaction.
Sh. 53623	24/2/39	Erosion scrapings rubbed on to scarifications in mouth	No reaction..	—
Sh. 53619	10/3/39	Blood: 5 c.c., s.c.....	Reaction....	31/3/39. No reaction.
Sh. 53720	13/3/39	Blood: 0.01 c.c., s.c....	No reaction..	11/4/39. † B.T.
Sh. 53727	13/3/39	Blood: 0.001 c.c., s.c...	No reaction..	11/4/39. Reaction. Recovered.
Sh. 53630	30/3/39	Blood: 10 c.c., i.v.....	No reaction..	24/4/39. Reaction Recovered.
Sh. 53623	30/3/39	Erosion scrapings rubbed on to scarifications in mouth	No reaction..	3/5/39. Reaction. Recovered.

(† = died; other contractions as for Table 1).

Blood was removed from calf 7543 on 24.2.39 (15 days after infection) and stored in the refrigerator. On 4.3.39, 10 c.c. was inoculated intravenously into calf 7325 (Onderstepoort). No reaction

of any kind occurred during the 14 days observation period. Blood of this calf taken on the 10th day produced bluetongue in a sheep (53710).

The one definite result of this experiment is that calf 7543 became inapparently infected with bluetongue (see positive transmission to calf 7325, 15 days, and to sheep 53619, 29 days). Small but definite local lesions, in the form of superficial erosions, appeared on the lower lip, and scrapings from these erosions contained bluetongue virus. (The scraping produced no lesions when applied to scarifications in the mouth of sheep 53623.) However, one cannot be certain that the scrapings, *per se*, were infective; it is possible that the blood removed with the erosions contained sufficient virus to produce the disease. In an attempt to check this point 2 sheep (53720 and 53727) were inoculated subcutaneously with 0.01 cc. and 0.001 cc. respectively of blood of calf 7543. No reaction occurred. The reason for this may have been the time at which the blood was taken—32 days after the original infection of the calf. At this stage the blood would possibly have been non-infective even in a large dose; it will be noticed that 10 cc. taken on the 49th day failed to set up bluetongue.

Experiment 5.—An attempt was made to ascertain whether the erosion scrapings of calf 7543 (Experiment 4) would produce lesions if inoculated into the buccal mucous membrane of bovines. With this end in view, the tongue, dental pad, and lower lips of a normal calf 7682 (Kaalplaas) and of a bluetongue-immune calf 7711 (Onderstepoort) were scarified and inoculated with an emulsion of scrapings, and at the same time the emulsion was given intravenously to sheep 53614 (noted in Table 2). Calf 7711 was considered to be immune for the following reason. On 15.10.38, it received virus (blood, sheep 52903) on the scarified buccal mucous membrane. No reaction (local or general) occurred. On 1.2.39 it received 20 cc. of virus (blood, sheep 52759) intravenously and did not react during the observation period of 23 days; its blood (5 cc. and 10 cc. amounts), taken on the 9th and on the 57th day after the intravenous injection of virus did not produce bluetongue in sheep (52749 and 52904) and these sheep were later shown to be susceptible to bluetongue virus. It may be added that at the time (30.3.39) of taking the second sample of blood, calf 7711 received 10cc. of virus (blood, sheep 53696) intravenously. No reaction occurred, and its blood, taken 11 days later, failed to produce bluetongue in sheep 53648. It would thus appear that the original inoculation by scarification on 15.10.38 produced an inapparent infection; unfortunately we took no steps at the time to prove this by the sub-inoculation of blood into sheep.

The application of the erosion scrapings of calf 7543 to the scarified buccal mucous membranes of calves 7682 and 7711 on 23.2.39 produced no reaction whatever, although the same material produced bluetongue when given intravenously to sheep 53614. As mentioned under experiment 4, there is no proof that the scrapings contained the virus; sufficient blood may have been removed with the scrapings to account for the result. Nevertheless, one is in the position to state an inoculum, containing sufficient virus

to set up bluetongue when given intravenously to a sheep, failed to produce any recognizable reaction when applied to the scarified buccal mucous membrane of a calf.

Experiment 6.—To the scarified buccal mucous membrane of an Onderstepoort calf (7405), virus (blood, calf 7543, see Experiments 4 and 5) was applied. Calf 7543 was infected by intravenous inoculation on 9.2.39, blood was removed on 24.2.39, and held in the refrigerator until 4.3.39, and on that day was inoculated into calf 7405. On the 7th day, 3 small (0.25 to 0.75 cm. in diameter) roughly circular, very superficial erosions appeared on the lower lip of calf 7405. The lesions had a "punched-out" appearance, were non-inflammatory and had a yellowish-grey base. Healing was complete on the 13th day. No thermal or constitutional reaction occurred. Scrapings of these lesions, removed on the 6th day after their first appearance, did not set up bluetongue when given intravenously to a sheep and blood, taken 14 days after the original scarification, also failed to produce bluetongue in a sheep.

Experiment 6a.—In 2 calves, 7543 (Experiment 4) and 7405 (Experiment 6), erosions had appeared on the lower lip after the administration of bluetongue virus, in the case of 7543 by intravenous injection and application to scarifications on the buccal mucous membrane, and in the case of 7405 by application to scarifications only. The lesions were of the mildest nature, caused no inconvenience, would have been missed but for careful search and were unaccompanied by a systemic reaction. We could not convince ourselves that they were the result of infection by bluetongue virus but considered their most probable cause was the trauma produced by the scarification. If the reaction in calf 7405 was due to bluetongue, there was every likelihood that it would become immune. The only way of proving this was to inoculate it with virus and after a suitable interval to subinoculate its blood into a susceptible sheep. The absence of a reaction in the sheep would indicate that the calf was immune. The results are collected in Table 3.

The results were quite clear-cut. Calf 7405 was not immune as shown by the positive transmission to sheep 53641; calves 7586 and 7682 were not immune and calf 7711 was immune as proved by the failure of transmission to sheep 53648. We can conclude that what caused the erosions on the lip of calf 7405 did not, at the same time, produce immunity to bluetongue.

DISCUSSION.

In our opinion, we failed to produce a recognizable disease in cattle with bluetongue virus (blood of infected sheep or cattle). In four animals, insignificant lesions appeared in the mouth. Those appearing in 2 animals (7697, Experiment 1 and 7585, Experiment 2) were so small that only a careful search revealed them and there is no doubt that they were the result of the scarification wounds. Calf 7543 (Experiment 4) was infected by inoculating blood intravenously and applying it to scarifications on the buccal mucous membrane. Small, very superficial, non-inflammatory erosions appeared on the lower lip on the 15th day after infection. Both the

SUSCEPTIBILITY OF CATTLE TO BLUETONGUE.

blood and the erosion scrapings contained bluetongue virus, but the scrapings, when applied to scarifications on the buccal mucous membrane of a susceptible calf (7682, Experiment 5), failed to produce a lesion. In the last experiment of this kind virus was rubbed into scarifications on the tongue, lower lip, and dental pad of calf 7405 (Experiment 6). On the 7th day erosions, similar to those found in calf 7543, appeared on the lower lip. In spite of this, calf 7405 did not develop immunity to bluetongue (Experiment 6a). The point that we are about to make will be better appreciated if the calves, the route of injection of virus, and the presence or absence of any local reaction are tabulated.

TABLE 3.

Experiment to ascertain whether Calf 7405 had developed Immunity to Bluetongue (Exp. 6a).

Animal.	History.	Present Inoculum.	Subinoculations.	Result of Subinoculation.
Calf 7405.....	4/3/39. Scar. buccal m.m. B.T. virus. Erosions produced (Exp. 6)	30/3/39. 10 c.c. i.v. virus (blood, sheep 53696)	11/4/39. 10 c.c. i.v. blood calf 7405 into sheep 53641 21/4/39. 5 c.c. i.v. blood, calf 7405 into sheep 53650	Reacted (B.T.) and recovered I.T. No reaction. I.T. Reacted and recovered.
Calf 7586.....	Normal calf O.P.	30/3/39. As calf 7405	11/4/39. 10 c.c. i.v. blood, calf 7586 into sheep 53705	Died (B.T.).
Calf 7682.....	23/2/39. Scar. buccal m.m. with erosion scrapings of calf 7543. No reaction (Exp. 5)	30/3/39. As calf 7405	11/4/39. 10 c.c. i.v. blood, calf 7682 into sheep 53734	Died (B.T.).
Calf 7711.....	Immune to B.T. (Exp. 5)	30/3/39. As calf 7405	11/4/39. 10 c.c. i.v. blood, calf 7711 into sheep 53648	No reaction. I.T. Reacted (B.T.) and recovered.

(B.T. = bluetongue; I.T. = immunity test; O.P. = Onderstepoort; i.v. — intravenously; scar. = scarified; m.m. — mucous membrane).

It will be observed that a local lesion was produced only when the buccal mucous membrane had been scarified. When the inoculation was by the intranasal, subcutaneous, or intravenous routes, mouth lesions were not produced. In three instances inoculation by the combined scarification and intravenous routes led to no local lesion although the blood used contained virus. In another three cases, scarification alone (in one instance, saline applied and in 2 others, erosion scrapings applied) did not lead to the formation of an erosion.

TABLE 4.
The Route of Injection and the Presence or Absence of a Local Lesion.

Calf.	Route of Injection.	Local Lesion.
7697	Scarification (blood).....	Positive (tiny pimple).
7697	I.N. (blood).....	Negative.
7697	S.C. (blood).....	Negative.
7595	Scarification (saline).....	Negative.
7595	I.V. (blood).....	Negative.
7585	Scarification (blood).....	Positive (tiny erosions).
7468	Scarification and I.V. (blood).....	Negative.
7700	Scarification and I.V. (blood).....	Negative.
7494	Scarification and I.V. (blood).....	Negative.
7543	Scarification and I.V. (blood).....	Positive (small erosions).
7325	I.V. (blood).....	Negative.
7682	Scarification (erosion scrapings)....	Negative.
7711	Scarification (erosion scrapings)....	Negative.
7405	Scarification (blood).....	Positive (small erosions).
7586	I.V. (blood).....	Negative.
7682	I.V. (blood).....	Negative.
7711	I.V. (blood).....	Negative.

(I.N. = intranasal; other abbreviations as in Table 1).

We consider that the results point to the scarification, *per se*, playing the big, if not the only, part in the production of the tiny erosions. And even if we grant that the bluetongue virus may have had a share in the process, we consider that these minute, difficult-to-find lesions are not to be compared as to size and gravity with the lesions found by Bekker *et al.* in naturally-infected bovines. The only definite conclusion we can draw from our work is that bluetongue virus produces an inapparent disease in cattle. Although the animals appeared healthy and exhibited no thermal, constitutional, foot, or skin lesions, yet virus could be demonstrated in their blood 29 days but not 49 days after the infective inoculation.

In many respects our results differ from those of Bekker *et al.* They claim to have produced mouth lesions, thermal reactions, and in a few cases, constitutional (obvious illness) reactions. We are not impressed by the temperature charts of their calves 5201 and 5257 (pp. 506 and 507) infected by intralingual inoculation of virus. The temperature of calf 5257 rose to 103.1° F. on the 4th day and thereafter remained at 102° F. or below except for one rise to 102.6° F. Such temperatures are definitely within normal limits. That of calf 5201 reached limits (103.8° to 104° F) that could be termed abnormal but a rather low starting temperature (101.1° F.) makes the chart look more impressive than it really is. One is struck by the early-appearing thermal rise in their calves, very often on the 3rd day and once on the 2nd day. At the present moment, the much more susceptible sheep commences to react to their virus ("Bekker") on the 5th day at the earliest and usually not until the 6th or 7th day. Another point that requires explanation is why mouth lesions not infrequently appeared before the first rise in temperature or why they appeared without a rise in temperature at all. For example, calf 9 (p. 457) had an elevation in temperature

on the 10th day, but on the 5th day superficial ulcers appeared on the upper lip. Again, it is a little difficult to reconcile the appearance of the ulcers on the lip of calf 5407 (p. 463, photograph on p. 418) with the inoculation of bluetongue virus. The temperature rose to 104° F. on the 3rd day, stayed at this level for 24 hours and thereafter remained within normal limits. Yet, although the reaction was almost negligible, definite ulcers were present on the lower lip on the 3rd day. We have a very clear recollection of these particular lesions and in size, "severity," and degree of inflammation they were greatly in excess of our tiny, very superficial erosions. They resembled much more closely the erosions we produced with erosive stomatitis virus. Whilst early-appearing hyperaemia, excoriation, and erosion-formation could be symptoms of bluetongue in cattle, we would point out that hyperaemia of the buccal mucous membrane in bluetongue-infected sheep seldom appears until the thermal reaction is well advanced and that coronitis appears at a still later date.

Although de Kock, du Toit and Neitz (1937) and de Kock, van Heerden, du Toit and Neitz (1937) isolated bluetongue virus from the blood of cattle living under veld conditions, they did not record the presence of mouth lesions in such animals or in bovines experimentally infected, and this despite full knowledge of, and participation in, the work of Bekker *et al.*

As stated in the introduction to this article, we commenced this piece of research after working on erosive stomatitis of cattle. We had been able to transmit this disease by the application of erosion scrapings to the scarified buccal mucous membrane, but had not succeeded in demonstrating bluetongue virus either in local lesions or blood. To our knowledge, Bekker *et al.* did not attempt the reproduction of lesions by applying erosion or ulcer scrapings locally. We can only speculate on the result, but there is no doubt that the failure to carry out the experiment was a serious omission. A counter-argument could be that lesions were produced by the intravenous inoculation of virulent blood alone. But, if the local lesions had been produced by a virus of the erosive stomatitis type, the indiscriminate "mouthing" of healthy and infected cattle, and the failure to adopt rigid isolation and disinfection measures would have been sufficient to ensure infection without the intervention of bluetongue virus.

A possible criticism of our work is that our virus had been subjected to many passages (14) through sheep and had in the process lost pathogenicity for cattle. However, we would recall that Bekker *et al.* claim to have produced the lesion in calf 5407 with virus that had been passed through 2 sheep in series. We would also recall that the "Bekker" strain of virus produces, at the present time, as severe a disease in sheep as it did immediately after isolation from cattle. We intend to repeat part of the work with a virus from cattle whenever we are fortunate enough to isolate such a strain.

Thus, because of our own results and because of the reasons given in our criticism of the work of Bekker *et al.*, we cannot unreservedly accept their view that bluetongue of cattle is

characterized by a rise in temperature, constitutional symptoms, and mouth or foot lesions. However, we do appreciate that a different set of circumstances such as a virus direct from cattle, cattle highly susceptible to bluetongue, and altered nutritional, environmental, and climatic conditions, might give different results.

CONCLUSIONS.

(1) Bluetongue virus inoculated intravenously, subcutaneously, intranasally, or through scarifications on the buccal mucous membrane did not cause any apparent illness in cattle.

(2) Inoculated cattle developed a *maladie inapparente*.

(3) The ability of bluetongue virus to cause lesions in the buccal cavity of cattle is doubted.

REFERENCES.

- BEKKER, J. G., DE KOCK, G. v. d. W., AND QUINLAN, J. B. (1934). The occurrence and identification of bluetongue in cattle—the so-called pseudo-foot and mouth disease in South Africa. *Onderstepoort J.*, Vol. 2, pp. 393-507.
- DE KOCK, G., VAN HEERDEN, C. J., DU TOIT, R., AND NEITZ, W. O. (1937). Bovine Theileriasis in South Africa with special reference to *Theileria parva*. *Onderstepoort J.*, Vol. 8, pp. 9-123.
- DE KOCK, G., DU TOIT, R., AND NEITZ, W. O. (1937). Observations on bluetongue in cattle and sheep. *Onderstepoort J.*, Vol. 8, pp. 129-180.
- MASON, J. H., AND NEITZ, W. O. (1940). Erosive stomatitis of cattle. (This Journal.)

Erosive Stomatitis of Cattle.

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Virus Diseases.

INTRODUCTION.

In June 1938 foot-and-mouth disease broke out in the cattle in the Nqutu Native Reserve, Natal. All infected and in-contact animals were slaughtered and buried, and the movement of cattle in the country immediately surrounding the "slaughtered-out area" was restricted until the authorities were satisfied that the disease no longer existed. Every animal in this "restricted area" (Klip River district) was examined ("mouthed") weekly and any deviation from the normal reported. In September, lesions, some slightly resembling, and others closely resembling, those of foot-and-mouth disease, were noted. A field laboratory was set up in the "slaughtered-out area", a few miles from the "restricted area". When once we had satisfied ourselves that the infection found in September was not foot-and-mouth disease, we carried out more detailed experiments at Onderstepoort.

THE DISEASE IN THE FIELD.

Two widely-differing forms of stomatitis were encountered. The evidence available indicates that these were not manifestations of the same disease. One, that will not be dealt with in detail, was, for convenience sake, termed "scaly" or "furry" tongue; the other, erosive stomatitis, was more common and formed the main subject of investigation.

"Scaly" Tongue.—A tongue, affected with this disease, had lost all or a portion of its superficial epithelium. When the epithelium was totally denuded, the tongue was smooth and eel-like. When only a portion was lost, a whorled appearance was produced because the scaling-off took place in an irregular fashion. The remaining epithelium could usually be removed by scraping with a finger-nail or a blunt scalpel.

Erosive Stomatitis.—Some lesions had a faint resemblance to old foot-and-mouth disease erosions; they were flatter than healing cuts, were covered with a greyish material, and when this was scraped away, a papilliform non-bleeding surface was left. In only a few animals were lesions seen, closely resembling those of foot-and-mouth

disease. Mr. A. M. Diesel*, Senior Veterinary Officer, Natal, describes one (later seen by one of us, J. H. M.) "When first seen (16.9.38), the tongue lesion in the 3-year-old black cow on Roosdal farm, was almost completely circular, about 4 cm. to 5 cm. in diameter, showed a regular papilliform and even base, clean-cut and regularly circular edges and was nearly 0.8 cm. deep. No change was observed in the mucous membrane of the mouth, nor did the animal show any foot lesions or any clinical symptoms of ill health. A day or two later, the lesion had become almost filled with a pseudo-membranous deposit, which when scraped away left a uniform reddened (no longer papilliform) base When seen about 16 days later, a circular scar about 3 cm. in diameter was seen . . . The animal never, at any time, showed any general disturbances of the buccal mucous membrane and evinced no clinical signs of ill-health. No foot lesions were ever seen. Both (stock) inspectors maintained that it salivated copiously on the first day . . . On the 21.9.38 a similar but slightly smaller lesion was seen in an 18-month-old animal on the same farm. It, too, showed the thick membranous greyish deposit after 36 hours and healed out in the same way, no changes being noticeable on the buccal mucous membrane or feet, and no clinical evidence of systemic disturbance was exhibited, also no copious salivation"

It was from the lesion in this bovine that material was obtained that gave successful artificial transmission.

In no affected animal were foot lesions, excessive salivation, or systemic disturbance observed. The spread of the disease from animal to animal was very slow, only the rare new case being detected at each new inspection, and the disease was confined, in the main, to bovines below the age of three years.

It is impossible to say whether "scaly tongue" was produced by the same agent that caused erosive stomatitis. At no time did we reproduce "scaly tongue" artificially with erosive stomatitis material.

Erosive stomatitis could be distinguished from foot-and-mouth disease on the following clinical grounds (we quote from Mr. Diesel's report)—

- "(a) The absence of the truly irregular, jagged erosions of typical foot-and-mouth disease
- (b) Absence of that high degree of vascularity seen at the base of all foot-and-mouth disease lesions.
- (c) No "hotness" of the mouth and no copious salivation.
- (d) Absence of foot lesions.
- (e) Absence of systemic disturbances.
- (f) Apparent confinement of the condition to stock below the age of 3 years, and its failure to assume epidemic proportions."

* In a report to the Acting Director of Veterinary Services.

It is almost certain that the disease would have escaped notice if frequent inspection of the cattle in the "restricted area" had not been in force. It was because the stomatitis appeared in the cattle of such an area and because the Ngutu outbreak of foot-and-mouth disease had been of a mild, slowly-spreading nature that considerable effort was made to eliminate the possibility of its being foot-and-mouth disease.

EXPERIMENTS IN THE FIELD.

Attempts to infect guinea-pigs.

As attempts to infect guinea-pigs by the intraplantar inoculation of lesion scrapings failed completely, no point will be served by detailing the individual experiments. However, the following data indicate that a reasonably thorough attempt was made to prove the presence of foot-and-mouth disease. Material (scrapings of mouth lesions in buffer solution) from 18 bovines of 6 different farms was inoculated into 21 guinea-pigs. At least one passage, on three occasions 2 passages, and on one occasion 3 passages, of pad substance was carried out in fresh guinea-pigs. The pads were removed at the 48th to 72nd hour after the injection, ground-up in buffer solution and passaged. In a number of instances, scrapings from several bovines were pooled and injected intraplantarilly. In all, 51 guinea-pigs were used, without at any time an indication of vesicle formation being observed. The only reaction in the pad was a slight hyperaemia along the needle track.

Attempts to infect calves.

Three bovines were used, two from outside the restricted area and one from an infected farm (Roosdal). All were under 6 months old and showed no abnormality in the buccal cavity.

Calf 1.—Inoculated superficially (as for the intraplantar inoculation of guinea-pig pads) in 3 different places on the tongue with a suspension of scrapings of a tongue lesion of the calf on Roosdal farm (see calf noted in Mr. Diesel's report on page 160).

Observations:

After 24 and 48 hours: No abnormality.

After 72 hours: One inoculated area raised in the form of a pyramid, with the apex rounded; the base of the swelling was approximately 1.5 cm. in diameter and the height 0.75 cm.; no abnormality in the region of the other two areas.

After 96 hours: The swelling was ruptured, the opening small and the cavity filled with a dirty-grey cheesy material; the base of the cavity bled only very slightly when scraped and left a papilliform surface. A tiny superficial erosion was present at one of the other inoculation sites.

After 120 hours: Lesion flatter and filled with a dirty-grey cheesy material.

After 168 hours: Lesion flat and healing.

An emulsion of scrapings from the lesion of the Roosdal calf and from that of calf 1 failed to produce reactions when inoculated intraplantarilly into guinea-pigs.

Calf 2.—Inoculated intralingually, in 5 different areas, with emulsions or suspensions of the following materials—(1) culture (Gram-negative bacillus) isolated from the lesion of calf 1, (2) culture (staphylococcus) isolated from a "scaly" tongue, (3) culture (diphtheroid) isolated from a lesion on the tip of a bovine's tongue, (4) emulsion of scrapings from a lesion on a bovine's tongue (Potsdam case). No abnormality was noted during a 7 day observation period.

Calf 3.—Although guinea-pigs did not react when inoculated with scrapings from mouth lesions, the possibility existed that a virus was the cause of the naturally-occurring disease and that this virus could multiply in the guinea-pig pad without causing lesions. With this hypothesis in mind, an emulsion of scrapings of a lesion was passaged intraplantarilly 3 times in guinea-pigs and an emulsion of the hind pads of the third passage guinea-pigs was inoculated intralingually into calf 3. No reaction occurred during the 7 days the calf was under observation.

EXPERIMENTS CARRIED OUT AT ONDERSTEEPOORT.

Scrapings from lesions of 3 bovines were brought to the Institute in buffer solution (M/15 phosphate, pH 7.3) and infection experiments carried out in calves, sheep, guinea-pigs, rabbits, rats, and mice. It will save repetition if it is now stated no calf or sheep showed a thermal rise, obvious illness, foot lesions or excessive salivation as a result of attempted artificial infection. Most of the calves used were born at Onderstepoort and had been reared under tick-free conditions and were not older than 9 months; when the supply of these ran out, calves (one year old or under) from an adjoining farm, Kaalplaas, were used. The Kaalplaas animals were born and bred under veld conditions.

Throughout all the work, precautions were taken to prevent the spread of infection by clothing and hands. Rubber boots, gloves, and apron were worn and washed down with disinfectant between the examination of each calf. Rejected food, bedding, and excreta were placed in sacks and burned, and except in the first two experiments, a separate box was allotted to each calf.

Two experiments, to illustrate tongue, and lip and dental pad lesions respectively, will be recorded. Thereafter, summaries only will be given.

Experiment 1.—Three calves (7680, 7501 and 7571) were placed in the same box and each was inoculated in 3 different places on the tongue with emulsions of mouth scrapings brought from the field.

Calf 7680.—Inoculated with emulsion of scrapings from the tongue erosions of calf 1 (see p. 161). This material had been held in buffer solution for 11 days (9 days at refrigerator, and 2 days at room temperature).

Observations :

<i>Days after Inoculation.</i>	<i>Appearance of inoculated area.</i>
1	Apparently normal.
2	One area slightly raised, with small hole at summit.
3	Three erosions present in one inoculated area, oval or slightly elongated, 0.5 cm. to 1.0 cm. in longer diameter, edges ragged, no bleeding on scraping base, base papilliform, erosion filled with a grey cheesy material.
4	As day 3.
5	Erosions more extensive; one red but not raw at base; other two filled with greyish material.
6	Healing commencing. Erosions flatter.
7	Healing continuing. Calf killed.

NOTE.—No lesions developed on one area, on the 2nd, tiny erosions appeared on the 3rd day and followed a similar course, but in a miniature way, to that described above and the lesions developing on the 3rd area are those described. No lesions developed on any other part of the buccal mucous membrane and guinea-pigs, inoculated intraplantarilly with scrapings taken on the 3rd day, did not react.

The reaction obtained in calf 7680 was very similar to that got in calf 1 and the final erosion could not be distinguished from that present on the tongue of the original Roosdal bovine. To save repetition such a reaction will be recorded as typical tongue lesion.

Calf 7501: Inoculated with emulsion of scrapings of several lesions of a bovine on farm Potsdam. This material had been held in buffer solution for 10 days (8 days at refrigerator, and 2 days at room temperature).

No reaction occurred during the 7 days' observation.

On the 7th day, this calf was inoculated intralingually, on this occasion with material from the tongue erosions of calf 7680. During an observation period of a further 14 days, no lesion appeared on the tongue, but on the 4th day a crop of small, very superficial, nearly confluent erosions appeared on the muzzle, and on the 5th day 3 small erosions developed on the dental pad. On both sets of erosions greyish yellow crusts formed; these could be scraped off only with difficulty and left a very shallow depression with an entire edge and a pink non-bleeding base. Healing had occurred on the 11th day after the inoculation of the tongue.

Calf 7571: Inoculated with emulsion of scrapings of a lower lip erosion of a cow on farm Ntabeni. This material had been held in buffer solution for 9 days (7 days at refrigerator temperature and 2 days at room temperature).

No lesions developed at the points of inoculation on the tongue, but on the 7th day, 7 superficial erosions appeared on the dental pad and 7 on the lower lip. These varied in diameter from 0.25 cm. to 1.0 cm., were dirty greyish-yellow in colour, and followed the same course as those recorded for calf 7501.

Comment.—Calves 7501 and 7571 did not react on the tongue (inoculation site) but did react, after a considerably lengthened incubation period, on the muzzle, dental pad, and lower lip. As they were in intimate contact with a reacting bovine (7680), the chance is that they were infected through contact. To check this point, a fresh calf (7668) was placed in contact with two reacting bovines (7501 and 7700) for 14 days. Two tiny, shallow erosions developed on the dental pad and a number of pin-point depressions appeared on the muzzle. All healed in a few days. It is doubtful if this can be regarded as a positive result. The dental pad lesions appeared on the second day of contact, which is about one day too early for the development of the “pearly” precursor (to be discussed later) of an erosion even when the pad is deliberately infected by scarification; the muzzle lesions were tiny and required careful observation for detection.

Experiment 2: Calf 7592 was inoculated on the tongue by superficial injection and on the dental pad and lower by scarification, with an emulsion of scrapings of mouth lesions from artificially infected calves 7702 and 7585. This material represented the third passage in calves.

Observations:

<i>Days after Inoculation.</i>	<i>Appearance of inoculated areas.</i>
1	Apparently normal. Scarification marks visible.
2	As day 1.
3	<i>Dental pad:</i> 6 pin-head-sized whitish-yellow spots surrounded by a red border. The spots looked like tiny pearls under the mucous membrane. <i>Lower lip and tongue:</i> Apparently normal.
4	<i>Dental pad:</i> “Pearls” breaking down to form superficial erosions. <i>Lower lip:</i> “Pearls” commencing. <i>Tongue:</i> Apparently normal.

*Days after Inoculation.**Appearance of inoculated areas.*

5

From now until the 10th day, when healing commenced, the erosions, at first small, superficial, with a white glistening base and a red border, coalesced to form fairly extensive erosions. These larger lesions resembled the smaller ones in appearance. The edges were ragged, the base glistening and moist, and the outline irregular. Healing occurred as for a traumatic injury, and if the original lesion had been large a visible scar was left.

The above description is fairly typical of those lesions which commenced with "pearl" formation. Occasionally, the "pearls" could be detected on the 2nd day after inoculation, especially if the lip or dental pad was vigorously rubbed with the finger. Erosion formation could be hastened and intensified by scraping a few "pearls" with a blunt knife.



Lesions on tongue of calf 7444 (artificial infection).

In Table 1, the passages carried out in calves are recorded. It will be seen that the disease was transmitted in series through 5 calves, and that lesions were produced in the tongue (the only site inoculated) of the first three animals and in the pad and lip only of the last 2 calves, although the tongue was also inoculated. The only tongue lesions obtained were in these first three calves.

TABLE 1.
Passages in Calves.

Donor.	Recipient.	Inoculum.	Result.
Roostal calf. (Natural infection)	Calf 1.	T.-T.	(T.)
Calf 1.	C. 7444	T.-T.	(T.)
C. 7444	C. 7966	T.-T.	(T.)
C. 7696	C. 7592	T.-T.P.L.	(P. & L.)
C. 7592	C. 7603	P.L.-T.P.L.	(P. & L.)
T.-T.....	Tongue lesion scrapings inoculated into tongue only.		
T.-T.P.L.....	Tongue lesion scrapings inoculated into tongue, dental pad, and lower lip.		
P.L.-T.P.L.....	Dental pad and lower lip lesions inoculated into tongue, dental pad, and lower lip.		
(T.).....	Tongue lesions.		
(P. & L.).....	Dental pad and lower lip lesions.		

The foregoing experiments merely showed that some infection was being passed from calf to calf but did not indicate the nature of the infection—whether virus or bacterium. To check this point, infectious material was passed through “Gradocol” membranes and the infective power of the filtrate tested on calves.

Gradocol Filtration.—A homogeneous suspension of scrapings of recently formed erosions was made in 10 per cent. (horse) serum-saline. This was spun at 4,000 r.p.m. for half-an-hour and the supernatant fluid re-spun at 13,000 r.p.m. for a further 20 minutes. The final crystal-clear supernatant was then passed through gradocol membranes; if 2 membranes of different pore size were used, the fluid was passed first through that with the larger pores. The pressure (one atmosphere) was obtained from a cylinder of compressed nitrogen and the temperature was between 22° C. and 25° C. The time required for filtration varied from 15 to 90 seconds and the volume of fluid filtered was 20 c.c. or more*. The filtrates were subjected to sterility tests on blood agar, chick-embryo-extract agar, serum-broth and meat-particle broth plus chick-embryo extract. The tubes of medium were incubated at 37° C., some aerobically and others anaerobically, for one week. No bacterial growth was obtained in any instance.

The results of injecting a number of filtrates into susceptible calves are recorded in Table 2.

Filtrates, sterile by bacteriological tests, produced typical lesions in 5 of the 6 calves inoculated. It will be noticed that the non-reactor received the inoculum in the tongue only and that in none of the 5 reactors was a tongue lesion produced. This confirms the results of “straight” passage, where the tongue appeared to be less susceptible than the lip or dental pad.

* For this, the filtration part of the work, we are indebted to our colleague, A. Polson.

TABLE 2.

Result of Injecting Gradocol Filtrates into Calves.

Donor.	Membrane. (nix.)	Site of inoculation.	Recipient.	Result.
C. 7444.....	1,350	T.P. & L.	C. 7702	R. (P & L.)
	Unfiltered.	T. only.	C. 7696	R. (T.)
	1,350	T.P. & L.	C. 7585	R. (P. & L.)
C. 7702.....	500	T.P. & L.	C. 7711	? (P. & L.)
	Unfiltered.	T.P. & L.	C. 7272	R. (P. & L.)
C. 7702	800	T.P. & L.	C. 7596	R. (P. & L.)
C. 7585	Unfiltered.	T.P. & L.	C. 7592	R. (P. & L.)
C. 7571				
C. 7700	435	T. only.	C. 7443	N.
C. 7680	Unfiltered.	T. only.	C. 7444	R. (T.)
Calf 1.				
C. 7576	390	T.P. & L.	C. 7520	R. (P. & L.)
C. 7592	Unfiltered.	T.P. & L.	C. 7603	R. (P. & L.)

T.=tongue; P.=dental pad; L.=lower lip; N.=no reaction; R.=reaction.

It will be appreciated that no serious attempt was made to estimate the size of the infecting agent. Anything approaching an accurate end-point could have been reached only with the use of a much larger number of young susceptible calves than was at our disposal. The results did show that the causal agent readily passed through membranes with an A.P.D. of about 400 μ and that it was not cultivatable in cell-free culture media.

Cultivation on the Chorio-allantoic Membrane of Eggs.—The technique employed has been described in detail by Alexander (1938). Fertile eggs containing 8-day-old embryos were used and, after inoculation of the membranes, were incubated at 37° C. for a further 5 to 6 days when a passage was made. The original inoculum was a bacteriologically sterile gradocol filtrate. Calves were inoculated on the tongue (intralingual injection), dental pad, and lower lip (scarification) with emulsions of the chorio-allantoic membrane. (Table 3 summarizes the results.)

TABLE 3.

*Cultivation of the Infective Agent on the Chorio-allantoic Membrane.**Series 1.*

The original inoculum, an 800 μ filtrate from calves 7702 and 7585, was infectious for calf 7596 (see Table 2).

Calf.	Egg Generation.	Inoculum.	Result.
7570	1	C.A.M.....	Negative.
7588	2	C.A.M. & E.	? positive; tiny white spots with red borders on lower lip; did not form erosions.
7458	3	C.A.M.....	Negative.
7480	3	E.....	Negative.

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Series 2.

The original inoculum, a 560 m μ filtrate from calf 7359 was not tested for infectivity.

Calf.	Egg Generation.	Inoculum.	Result.
7530	4	C.A.M.	Positive; definite "pearls" on lip and pad on 2nd day. Broke down to form erosions. Nil on pad.
7550	9	C.A.M.	Negative.

(C.A.M. = chorio-allantoic membrane; E. = embryo).

The results indicate that the infective agent, which will now be called the "virus", grew on the chorio-allantoic membrane of fertile eggs. The lesions produced in calf 7588 of series 1 were not typical and do not constitute a positive result. On the other hand, the lesions in calf 7530 of series 2 were definite and typical. The membranes were sterile bacteriologically so that a bacterium, as a cause, may be ruled out. The inoculum for calf 7530 was composed of membranes of the 4th egg passage so that it is unlikely that a carry-over of the originally-inoculated virus (gradocol filtrate) was responsible for the lesions.

Keeping qualities of virus.

As stated earlier, the virus survived 11 days (9 days at refrigerator, and 2 days at room temperature and, in subsequent work, it was shown to remain viable for 21 days at refrigerator temperature. As with most of the experiments in this investigation, we lacked sufficient calves to investigate fully the different properties of the virus. However, we were able to show that scrapings emulsified in 50 per cent. (horse) serum saline and dried from the frozen state and held at refrigerator temperature, remained infective for 6 weeks.

Immunity.

Calves which had fully recovered from artificial infection were subjected to a further inoculation on the tongue, dental pad, and lip. Table 4 records the results.

TABLE 4.
Immunity Tests in Calves.

Calf.	First Inoculation.	Result.	Second Inoculation.	Result.
7243.....	Nil	—	16/1/39 T.P. & L.	R. (P. & L.).
7700.....	12/10/38 on T. & P.	R. (P.)	T.P. & L.	R. (P. & L.).
7585.....	4/11/38 T.P. & L.	R. (P. & L.)	T.P. & L.	Negative.

(Abbreviations as in Table 1).

Owing to the small number of animals used, definite conclusions cannot be drawn, but the indication is that the immunity was either of very short duration or weak, or both.

The Clocolan Virus.

Our colleague, E. M. Robinson, investigated an outbreak of stomatitis in cattle at Clocolan in the Orange Free State. His description of the lesions tallied with that given earlier for those of the cattle in the Klip River district. Scrapings of mouth erosions, emulsified in buffer solution, were brought to Onderstepoort and inoculated into a susceptible calf (tongue, dental pad, and lower lip). Lesions, indistinguishable in evolution, course, and appearance from those described were obtained on the pad and lip and the disease was successfully passed to two more calves. Clinically, the two diseases were identical.

Attempts to infect Sheep.

No local or general reaction was produced when virus in the form of erosion scrapings was inoculated into the tongue, dental pad, or lower lip of bluetongue susceptible sheep or when blood of reacting cattle was inoculated intravenously. The chief reason for carrying out these transmission experiments was the findings of Bekker, de Kock and Quinlan (1934). From the blood of cattle, affected with stomatitis and dermatitis and living in a foot-and-mouth-disease-infected area, they were able to isolate bluetongue virus in sheep. Table 5 summarizes our findings.

No reaction, local or general, was produced when sheep were inoculated, either locally, in the buccal cavity, or intravenously, with emulsions of erosion scrapings taken at the height of the local reaction. Further, the intravenous injection of blood, taken from calves at the height of the reaction produced no obvious effect. No sheep, subjected to this treatment, was immune to bluetongue at a subsequent immunity test. The blood of the original Clocolan cattle given intravenously to sheep produced no reaction and did not immunize against bluetongue. And finally "Bekker" bluetongue virus applied to scarifications on the tongue, dental pad, and lower lip of 2 sheep produced no local reaction but did, in one sheep, cause a general reaction with resulting immunity.

Throughout all this work, we kept in mind the work of Bekker, de Kock and Quinlan (1934) de Kock, du Toit and Neitz (1937), and de Kock, van Heerden, du Toit and Neitz (1937). These groups of workers isolated bluetongue virus from cattle. In the case of the first group of workers, the virus originated from cattle affected with stomatitis, and with it the authors produced stomatitis in bovines; in the latter case, the blood was obtained from cattle without stomatitis, but living under veld conditions and affected with "Tzaneen" disease (for details, see original articles). The results recorded in Table 5 show that we could not demonstrate bluetongue virus in the local lesions or in the blood of cattle artificially infected with erosive stomatitis. Since then, we have attempted to repeat the work of Bekker *et al.* with what we consider to be negative

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results (these experiments will be reported in more detail in another article), in spite of using the same strain of virus, "Bekker", as they did. The Bekker strain is undoubtedly bluetongue virus, apparently caused stomatitis in cattle in the hands of Bekker *et al.* and failed to do so in our hands, although it did set up a "maladie inapparente" in cattle, being recoverable in the blood about 3 weeks after intravenous inoculation.

TABLE 5.

*Attempts to infect Sheep with the Viruses of
Erosive Stomatitis and Bluetongue.*

Sheep.	Inoculum.	Route.	Result.	Date.	B.T. Immunity Test (Bekker Virus).
52710	9/11/38, erosion scrapings C. 7702 and C. 7585	T.P. & L.	No reaction.	3/1/39	† B.T.
52671	As 52710.....	T.P. & L.	No reaction.	3/1/39	Reacted B.T. and recovered.
52906	13/10/38, erosion scrapings C. 7571	T. & P.	No reaction.	3/1/39	Reacted B.T. and recovered.
52960	As 52906.....	I.V.	No reaction.	3/1/39	Reacted B.T. and recovered.
52732	25/10/38, 10 c.c., blood, C. 7444	I.V.	No reaction.	3/1/39	B.T. killed in extremis.
52952	25/10/38, 10 c.c., blood, C. 7444	I.V.	No reaction.	—	—
52952	5/11/38, 10 c.c., blood, sh. 52732	I.V.	No reaction.	3/1/39	B.T. killed in extremis.
52886	15/10/38, Bekker B.T. blood, sh. 52903	T.P. & L.	No reaction.	15/1/39	B.T. killed in extremis.
52874	As 52886.....	T.P. & L.	Reacted with temperature 4th-10th day. No mouth lesions.	15/1/39	No reaction.
52697	11/1/39, 10 c.c., blood of Clocolan cattle (field)	I.V.	No reaction.	1/2/39	Reacted B.T. and recovered.

(I.V. = intravenous; T.P. & L. = tongue, dental pad, and lower lip; † = died.)

In this article, we do not intend to discuss the possible reasons for the apparent discrepancy but will briefly record one experiment where heartwater and not bluetongue virus was isolated from the blood of a bovine infected with erosive stomatitis.

Bovine 7501.

10.12.37, born Kaalplaas, a heartwater-infected farm.

25.1.38, transferred to Camp 25 (Onderstepoort), heartwater-free camp.

31.3.38, transferred to Camp 22 (Onderstepoort), heartwater-free camp.

25.8.38, transferred to West Camp 61 (Onderstepoort), heartwater-infected camp.

4.10.38, transferred to Stable 16 (Onderstepoort), heartwater-free stable.

5 and 8.10.38. This calf became infected with erosive stomatitis at this period, probably through contact (experiment noted on p. 164) and was killed on 26.10.38. At no time during the period 4.10.38 to 26.10.38 did the temperature rise above normal limits and except for the stomatitis, the animal appeared to be perfectly healthy.

On 13.10.38, 10 c.c. of blood was given intravenously to sheep 52716; a thermal reaction and symptoms of heartwater was the result, with eventual recovery. This sheep did not react when tested at a later date with heartwater virus, but at a still later date, it died when inoculated with blue tongue virus (Bekker). Subinoculation of blood of sheep 52716 was carried out when the thermal reaction was at its height, and from the subinoculated sheep, further tests were made to determine the cause of the reaction. In brief the results were as follows:—The symptoms and post-mortem findings were those of heartwater; *Rickettsia ruminantium* was seen in the endothelial cells of the jugular vein; heartwater-immune sheep were immune to this disease and those immune to this disease were immune to heartwater; bluetongue-immune sheep were not immune to this disease and those immune to this disease were not immune to bluetongue.

Obviously at the time of the inoculation of sheep 52716, calf 7501 was either recovering from heartwater or suffering from an inapparent form of the disease. If, by chance, we had picked up bluetongue and not heartwater virus, we might, following the experience of Bekker *et al.*, have assigned to bluetongue virus the causal rôle in stomatitis.

Attempts to infect laboratory animals.—This work, entirely negative, was a continuation of that carried out in the field. Guinea-pigs and rats could not be infected on the hind pads or on the tongue nor rabbits on the tongue. No reaction was produced when known infective but bacteriologically sterile gradocol filtrates were injected intracerebrally into mice and guinea-pigs or intraperitoneally into mice.

DISCUSSION.

The disease described, erosive stomatitis, appears to be of no economic importance and warrants investigation only when it can be confused with foot-and-mouth disease. Uncertainty will arise only in circumstances such as those noted in this article.

Prentice (1913) described a similar disease in cattle shipped from Ireland to England. Constitutional symptoms and foot lesions were absent and in-contact sheep and pigs did not contract the disease. "Scaly" tongue was noted in many of the bovines. Norris and Mettam (1913) gave a more detailed description of this disease as it occurred in cattle in County Armagh. This description agrees in many points with that given for erosive stomatitis, but it would appear that "scaly" tongue lesions were more common. They were able to reproduce the disease by contact and by applying infective material to the scarified buccal mucous membrane, but pigs and sheep were not susceptible. Infection was not set up with bacteria isolated from lesions.

Ostertag and Bugge (1906) recorded a papular stomatitis in cattle. The disease could be transmitted by the subcutaneous injection of the blood of reacting cattle, the incubation period being 14 days or more. No fever or constitutional symptoms occurred. Small elevations surrounded by red zones appeared on the buccal mucous membrane. At first the elevations were red but soon became yellow-grey in colour; depressions appeared in them and erosions were produced. In one experiment they introduced fragments of lesions into pockets cut in the tongues of 5 calves. These animals reacted after 14 to 18 days but not at the points of inoculation. For this reason, we would suggest that the disease was not the same as erosive stomatitis.

Cadéac (1906) described a vesicular stomatitis, which appears to have much in common with erosive stomatitis. However, as no experimental work is recorded, a definite opinion cannot be given.

Finally, we have shown that bluetongue virus could not be isolated from either the blood or local lesions of bovines affected with erosive stomatitis and that bluetongue virus did not produce a stomatitis. On the evidence presented—filterability, growth on the chorio-allantoic membrane of the chick embryo, and failure of bacteria isolated from lesions to set up the disease—we are of the opinion that erosive stomatitis of cattle is a disease caused by virus, and has much in common with, if it is not the same as, "Armagh disease".

CONCLUSIONS.

1. A disease, erosive stomatitis of cattle, which has some resemblance to foot-and-mouth disease, is described.
2. It can be transmitted in series from bovine to bovine and is caused by a virus.
3. There is evidence that erosive stomatitis and "Armagh disease" are similar, if not the same.

ACKNOWLEDGMENTS.

We have pleasure in acknowledging our indebtedness to Dr. G. de Kock, Deputy-Director of Veterinary Services, for initiating this piece of research and for criticism and help in the conducting of it; to Mr. A. M. Diesel, Senior Veterinary Officer, Natal, for the help

and courtesy shown us during the field investigation and for permission to quote from his report on the naturally-occurring disease; and to Mr. J. H. B. Viljoen, Government Veterinary Officer, Ladysmith, for his unfailing willingness to find suitable material.

REFERENCES.

- ALEXANDER, R. A. (1938). Studies on the neurotropic virus of horsesickness VI. Propagation in the developing chick embryo. *Onderstepoort J.*, Vol 11. pp. 9-19.
- BEKKER, J. G., DE KOCK, G. v. D. W., AND QUINLAN, J. B. (1934). The occurrence and identification of bluetongue in cattle—the so-called pseudo-foot and mouth disease in South Africa. *Onderstepoort J.*, Vol. 2, pp. 393-507.
- CADEAC, C. (1906). Stomatite vésiculeuse. Pathologie Interne. Bouche-Pharynx-Estomac. *J.-B. Baillière et Fils*, Paris.
- DE KOCK, G., VAN HEERDEN, C. J., DU TOIT, R., AND NEITZ, W. O. (1937). Bovine Theileriosis in South Africa, with special reference to *Theileria mutans*. *Onderstepoort J.*, Vol 8. pp. 9-125.
- DE KOCK, G., DU TOIT, R., AND NEITZ, W. O. (1937). Observations on bluetongue in cattle and sheep. *Onderstepoort J.*, Vol. 8, pp. 129-180.
- NORRIS, J. H., AND METTAM, A. E. (1913). Reports of experiments conducted in connection with the suspected outbreak of disease in County Armagh. Appendix B. Report on Foot and Mouth Disease in Ireland in the year 1912. *Dept. of Agric. and Tech. Instruction for Ireland*. H.M. Stat. Office (Cd. 7103).
- OSTERTAG AND BUGGE. (1906.) Untersuchungen über eine maulseucheähnliche Erkrankung des Rindes ("gutartige Maulseuche", Stomatitis papulose bovis specifica). *Ztschr. Infektionskht.*, Vol 1, pp. 3-20.
- PRENTICE, D. S. (1913). Report by. Appendix A. Report on Foot and Mouth Disease in Ireland in the year 1912. *Dept. of Agric. and Tech. Instruction for Ireland*. H.M. Stat. Office (Cd. 7103).

Rinderpest in Buffaloes.—The Immunizing Value of Dried Goat Spleen Vaccine.

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THE value of the Burmese buffalo as a working animal is limited by considerations of shade and water. He is very sensitive to the sun, and for that reason for draught purposes is worked in the dense forest shade, and elsewhere is not used during the heat of the day. Opinions differ as to the relative merits of the buffalo and the ox for draught purposes, but there is no question about the great superiority of the buffalo in swampy ground and in ploughing paddy fields, for in the ploughing season paddy fields are mud baths, and mud baths and ponds are essential for the health of the buffalo. During the heat of the day the buffalo likes to wallow in ponds, with often only his nose above water, or in mud baths, from which he emerges with a protective covering of mud.

In a previous article (Pfaff, 1938) the position in regard to the effects of dried goat spleen vaccine on buffaloes was stated to be a little uncertain. Because of severe reactions field inoculators had reduced the dose for buffaloes, and considered that the smaller dose was less severe than the 0·0025 gram used for cattle. Since at that time there were no facilities at the laboratory for the investigation of this question, the reports from the field were acted upon, and the dose for buffaloes was reduced to 0·0004 gram, even though investigations had shown that in cattle the quantity of the virus did not influence the reaction. It was also reported from the field that spread of the disease from inoculated buffaloes had occurred, and that in many instances buffaloes had long-drawn-out reactions, leading to great loss of condition. The experimental investigation of these reports is now recorded.

Experiment 1, Table 1.

A preliminary experiment to determine the influence of the dose of vaccine on the reaction was done on young Indian buffaloes purchased in the neighbourhood of the laboratory. Frequent outbreaks of rinderpest had occurred in the areas from which the animals came, so they were expected to have some resistance to the disease. Although the buffaloes were kept in an open shed and were fed on green fodder, the conditions were not ideal, because there was

no water or mud in which the animals could wallow. Fifteen buffaloes were divided into five groups of three; one group was kept as controls and the others given vaccine in doses of 0.25 gram, 0.0025 gram, 0.00025 gram, and 0.000025 gram.

Details of the experiment are given in Table 1. This shows that two of the three animals that got 0.25 gram were immune to rinderpest, but the reaction of the third buffalo was no more severe than that caused by 0.00025 gram in three other animals. The reaction following the injection of 0.000025 gram was milder and occurred three or four days later than that caused by the larger doses.

Virulent blood was given 30 days after the vaccine with the following result:—

In the 0.25 gram group all proved immune.

In the 0.0025 gram group two proved immune and one died, but this animal developed no thermal reaction to the virus. It was considered that death was due to the severe reaction set up by the vaccine.

In the 0.00025 gram group all proved immune.

In the 0.000025 gram group one proved immune, one reacted and recovered, and one died.

Of the three control animals one died, and the other two recovered after reacting severely.

Although the animals had a considerable degree of resistance, this experiment indicated that the severity of the reaction was not related to the dose employed, but the minimum effective dose was probably 0.00025 gram: a solution estimated to contain one-tenth of that amount failed to immunize, probably because it contained no virus.

During the rains of 1939, forty adult Burmese buffaloes were brought from an area which had been free from rinderpest for many years. Throughout the experiment they were kept in a paddock in which there were many trees, providing deep shade, and a large pond in which they could wallow; green fodder was fed in abundance, and since the experiment was carried out at the beginning of the cold weather, conditions were ideal for buffaloes.

The following experiments were done:—

Experiment 2, Table 2.

To determine the influence of the dose of vaccine on the reaction. Four groups of four buffaloes got 0.25 gram, 0.0025 gram, 0.00025 gram and 0.000025 gram. Table 2 shows that the reaction provoked by 0.25 gram was no more severe than that provoked by 0.000025 gram. 0.000025 gram failed to immunize one animal which subsequently died of rinderpest in the immunity test, and in the other three animals in this group the reaction occurred slightly later than in those animals getting a bigger dose. The susceptibility of the animals is shown by the death from rinderpest within ten days of all three control animals.

Experiment 3, Table 2.

To determine if buffaloes can develop immunity to rinderpest by contact with buffaloes reacting to dried goat spleen vaccine. Three buffaloes, numbers 77, 53 and 79, were kept in close contact with sixteen buffaloes reacting to the vaccine. They developed no temperature reaction and on the 35th day were given cattle rinderpest virus. All died of rinderpest, so it must be concluded that in these three animals no transmission had occurred and no immunity had developed by contact with reacting buffaloes.

Experiment 4, Table 3.

To determine if long-drawn-out reactions may be caused by infection with rinderpest contracted soon after inoculation. Eight buffaloes were given cattle rinderpest virus three days after receiving varying doses of vaccine. The temperature of all returned to normal by the 18th day, whereas the temperature of animals not receiving virus returned to normal about ten to twelve days after inoculation.

DISCUSSION.

During the course of the experiment all the inoculated buffaloes lost a lot in condition, and this notwithstanding the fact that they were kept under ideal conditions. Those that got cattle virus three days after they were inoculated lost most in condition. Coccidia were not detected, but three animals had attacks of surra: in two of these the disease was detected soon after the animals arrived, and they were subsequently used as controls; in the third animal the disease flared up 21 days after inoculation. Surra may, therefore, be a complicating factor in the inoculation of buffaloes. The quantity of vaccine given does not affect the reaction, but it is possible that a very severe and long-drawn-out reaction may be due to infection soon after inoculation.

In buffaloes the mortality from rinderpest varies greatly; in some outbreaks it may be only 10 per cent. while in others it may approach 100 per cent. Experience has shown that in areas where the mortality is low goat spleen vaccine does not cause unduly severe reactions, but deaths may be expected in districts where outbreaks of the disease have not occurred for many years. The three control buffaloes in Experiment 2 and the three buffaloes used in Experiment 3 all died of rinderpest within eleven days. This, and the loss of condition in those animals given dried goat spleen vaccine, show that the Burmese buffaloes used in these experiments were more susceptible to rinderpest than the young Indian buffaloes used in Experiment 1; they were more susceptible than the most susceptible Burmese cattle. Nevertheless the vaccine killed none of the Burmese buffaloes, probably because they were in very good condition at the time of inoculation and were kept under ideal conditions. These experiments indicate that the vaccine may safely be used for buffaloes in good condition, provided they are well cared for and given at least thirty days' rest after inoculation.

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SUMMARY.

1. The dose of dried goat spleen vaccine has no influence on the reaction produced.
2. Immunity is not acquired by contact with reacting buffaloes.
3. Long-drawn-out reactions may be due to infection soon after inoculation.
4. Buffaloes require adequate care and rest after inoculation.

ACKNOWLEDGMENT.

I am indebted to Capt. S. R. Rippon, Director of Veterinary Services, Burma, for providing facilities for the work and for permission to publish this article.

REFERENCE.

PFAFF, G. (1938). Immunization against Rinderpest, with Special Reference to the use of Dried Goat Spleen Vaccine. *Onderstepoort Jnl. Vet. Sc. and An. Indust.*, Vol. 11, No. 2, pp. 263-330.

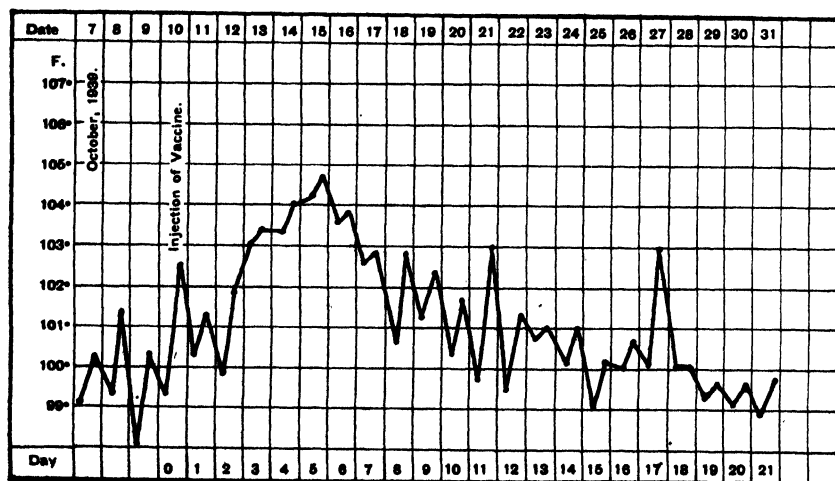


Fig. 1.—Temperature Chart of Buffalo 63, injected with 0.25 gram dried Goat Spleen Vaccine.

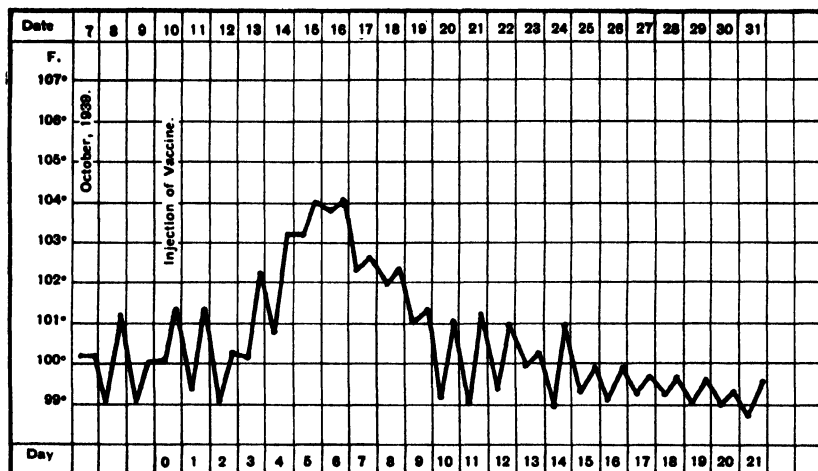


Fig. 2.—Temperature Chart of Buffalo 60, injected with 0.0025 gram dried Goat Spleen Vaccine.

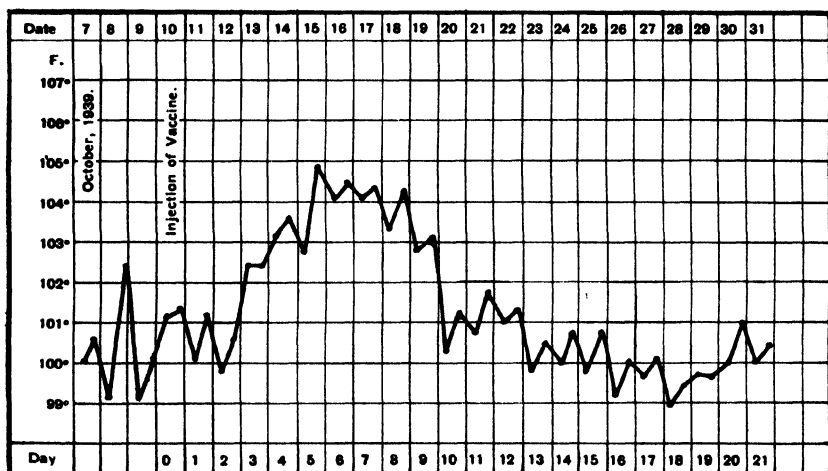


Fig. 3.—Temperature Chart of Buffalo 78, injected with 0.0025 gram dried Goat Spleen Vaccine.

RINDERPEST IN BUFFALOES.

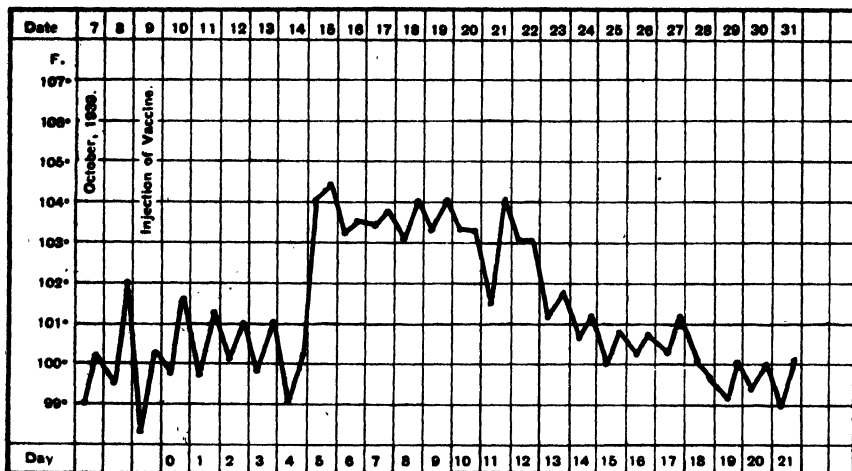


Fig. 4.—Temperature Chart of Buffalo 54, injected with 0.000025 gram dried Goat Spleen Vaccine.

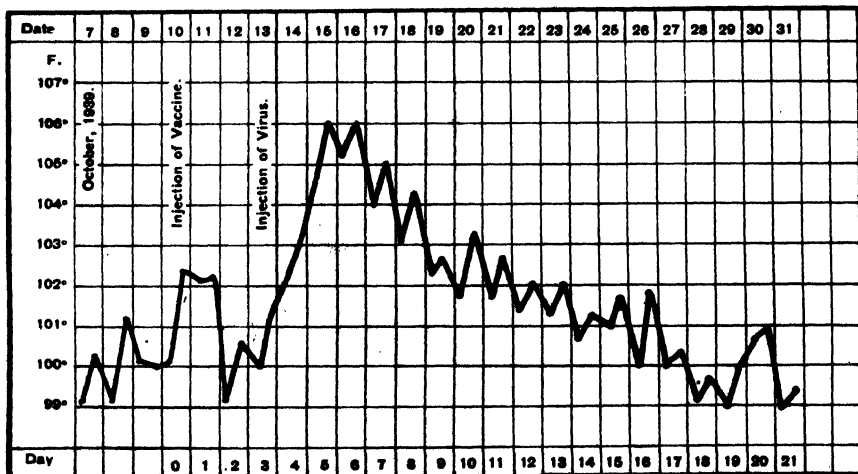


Fig. 5.—Temperature Chart of Buffalo 68, given virulent Cattle Rinderpest Virus 72 hours after injection of 0.000025 gram dried Goat Spleen Vaccine.

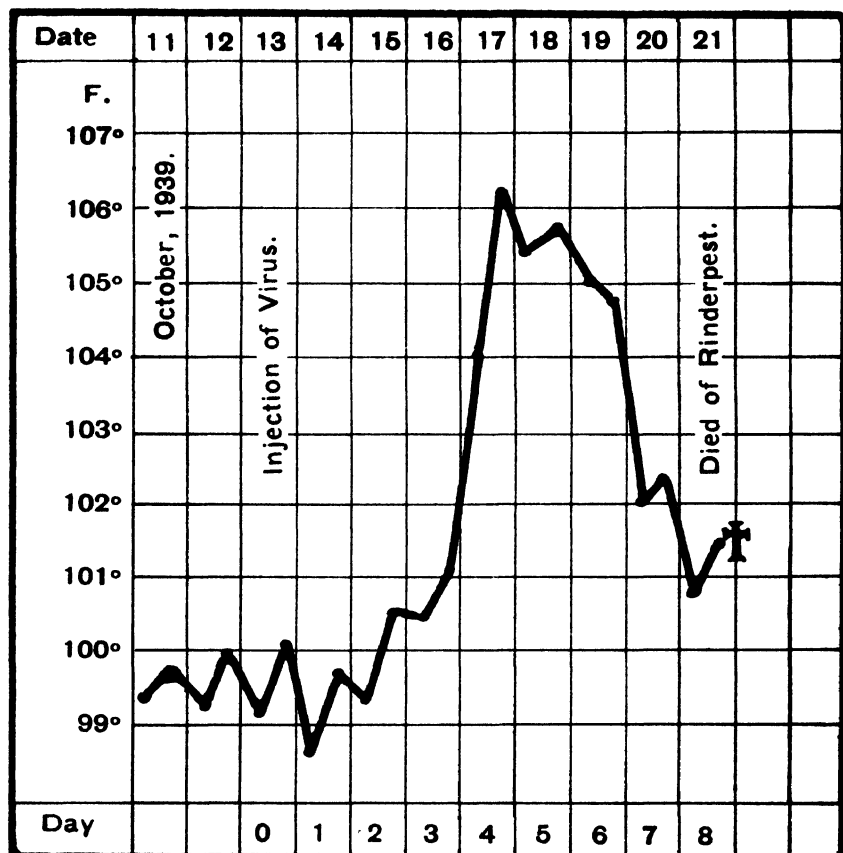


Fig. 6.—Temperature Chart of Control Buffalo 61, given virulent Cattle Rinderpest Virus.

APPENDIX.

TABLES 1 to 3.—Giving Details of Experiments described in the Text.

NOTE.—1. In Tables 1 to 3 the temperature in all cases refers only to that recorded before eight o'clock in the morning, the evening temperature being probably accentuated by the heat of the day and for that reason being disregarded.
 2. If immunity tests "Immune" indicates no reaction whatever.

TABLE I.

Experiment I.—To determine the effect of varying quantities of dried goat spleen vaccine on the reaction and immunity produced.

Number.	Age.	INJECTION OF DRIED GOAT SPLEEN VACCINE.			REACTION.				INJECTION OF VIRULENT CATTLE RINDERPEST VIRUS.			
		Date Injected.	Weight of Dried Goat Spleen in Grams.	Day of Initial Rise.	Day Peak Reached.	Peak Tempe- rature.	Rise in Tempe- rature.	Result.	Day Tempe- rature Return- ed to Normal.	Date Injected.	Quan- tity of Virulent Blood.	Result.
35	20 months.	15/12/38	0.25	—	—	—	—	No reaction....	—	13/1/39	2.5 c.c.	Immune.
38	18 months.	15/12/38	0.25	2nd	5th	102.6	2.4	Recovered....	14th	13/1/39	2.5 c.c.	Immune.
34	12 months.	15/12/38	0.25	4th	6th	102.6	2.0	No reaction....	13th	13/1/39	2.5 c.c.	Immune.
36	24 months.	15/12/38	0.0025	5th	5th	100.8	0.8	Recovered (mild reaction)	9th	13/1/39	2.5 c.c.	Immune.
39	18 months.	15/12/38	0.0025	—	—	—	—	Recovered....	—	13/1/39	2.5 c.c.	Immune.
46	12 months.	15/12/38	0.0025	1st	7th	102.8	2.4	Died on 40th day	24th	13/1/39	2.5 c.c.	No temperature re- action to virus.
37	28 months.	15/12/38	0.00025	4th	9th	102.0	2.0	Recovered....	17th	13/1/39	2.5 c.c.	Immune.
40	12 months.	15/12/38	0.00025	3rd	5th	102.0	3.0	Recovered....	12th	13/1/39	2.5 c.c.	Immune.
47	12 months.	15/12/38	0.00025	4th	5th	103.6	3.0	Recovered....	8th	13/1/39	2.5 c.c.	Immune.
43	36 months.	15/12/38	0.000025	7th	8th	101.4	2.0	Recovered....	12th	13/1/39	2.5 c.c.	Severe reaction; destroyed on 19th day because of emaciation.
41	12 months.	15/12/38	0.000025	6th	6th	102.2	3.0	Recovered....	11th	13/1/39	2.5 c.c.	Immune.
48	12 months.	15/12/38	0.000025	10th	10th	100.4	1.4	Recovered (very mild reaction)	12th	13/1/39	2.5 c.c.	Recovered after severe reaction.
44	18 months.	—	Control..	—	—	—	—	—	—	13/1/39	2.5 c.c.	Recovered after severe reaction.
45	12 months.	—	Control..	—	—	—	—	—	—	13/1/39	2.5 c.c.	Recovered after severe reaction.
50	6 months.	—	Control..	—	—	—	—	—	—	13/1/39	2.5 c.c.	Died of Rinderpest on 10th day.

TABLE 2.
Experiment 2.—To determine the effect of varying quantities of dried goat spleen vaccine on the reaction and immunity produced.

Buffalo Number.	INJECTION OF DRIED GOAT SPLEEN VACCINE.		REACTION.					INJECTION OF VIRULENT CATTLE RINDERPEST VIRUS.			
	Date Injected.	Weight of Dried Goat Spleen in Grams.	Day of Initial Rise.	Day Peak Reached.	Peak Temperature.	Rise in Temperature.	Result.	Day Temperature returned to Normal.	Date Injected.	Weight of Dried Bovine Spleen.	Result.
80	10/10/39	0.25	3rd	5th	102.6	No reaction	Recovered...	10th	13/11/39	0.01	Immune.
75	10/10/39	0.25	3rd	7th	104.4	4.4	Recovered...	10th	13/11/39	0.01	Immune.
67	10/10/39	0.25	3rd	5th	104.2	4.2	Recovered...	11th	13/11/39	0.01	Immune.
63	10/10/39	0.0025	3rd	5th	105.0	5.2	Recovered...	10th	13/11/39	0.01	Immune.
56	10/10/39	0.0025	4th	6th	104.2	3.0	Recovered...	11th	13/11/39	0.01	Immune.
72	10/10/39	0.0025	3rd	4th	103.0	3.6	Recovered...	12th	13/11/39	0.01	Immune.
52	10/10/39	0.0025	3rd	6th	103.8	3.8	Recovered...	10th	13/11/39	0.01	Immune.
60	10/10/39	0.00025	3rd	6th	104.4	4.4	Recovered...	13th	13/11/39	0.01	Immune.
58	10/10/39	0.00025	3rd	6th	104.0	4.0	Recovered...	13th	13/11/39	0.01	Immune.
78	10/10/39	0.00025	3rd	6th	Doubtful reaction on mild.		Recovered...	11th	13/11/39	0.01	Immune.
59	10/10/39	0.00025	3rd	6th	104.0	4.0	Recovered...	11th	13/11/39	0.01	Immune.
81	10/10/39	0.00025	3rd	6th	Irregular and doubtful		Recovered...	11th	13/11/39	0.01	Immune.
55	10/10/39	0.000025	3rd	6th	Irregular and doubtful		Recovered...	11th	13/11/39	0.01	Died of Rinderpest on 10th day.
62	10/10/39	0.000025	4th	7th	103.2	3.2	Recovered...	15th	13/11/39	0.01	Immune.
54	10/10/39	0.000025	5th	5th	104.0	4.0	Recovered...	15th	13/11/39	0.01	Immune.
74	10/10/39	0.00025	6th	7th	103.6	4.0	Recovered...	18th	13/11/39	0.01	Died of Rinderpest on 9th day.
61	—	Control..	—	—	—	—	—	—	13/11/39	0.01	Died of Rinderpest on 6th day.
70	—	Control..	—	—	—	—	—	—	13/11/39	0.01	Died of Rinderpest on 10th day.
69	—	Control..	—	—	—	—	—	—	13/11/39	0.01	Died of Rinderpest on 10th day.

Experiment 3.—To determine if buffaloes can develop immunity by close contact with buffaloes reacting to dried goat spleen vaccine.

77	Kept in close contact with animals in Experiment 2	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{	{
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RINDERPEST IN BUFFALOES.

TABLE 3.

Experiment 4.—To determine if long-drawn-out reactions may be caused by infection with rinderpest contracted soon after inoculation.

Buffalo Number.	INJECTION OF DRIED GOAT SPLEEN VACCINE.		REACTION.				INJECTION OF VIRULENT CATTLE RINDERPEST VIRUS.		Day Temperature Returned to Normal.	Result.
	Date Injected.	Weight of Dried Goat Spleen in Grams.	Day of Initial Rise.	Day Peak Reached.	Peak Temperature.	Rise in Temperature.	Date Injected.	Weight of Dried Bovine Spleen.		
65	10/10/39	0.25	4th	7th	104.2	4.2	13/10/39	0.01	17th	Recovered.
64	10/10/39	0.25	3rd	4th	104.4	4.4	13/10/39	0.01	17th	Recovered.
76	10/10/39	0.0025	4th	5th	104.8	4.8	13/10/39	0.01	13th	Recovered.
73	10/10/39	0.0025	3rd	6th	104.0	4.4	13/10/39	0.01	18th	Recovered.
71	10/10/39	0.00025	3rd	4th	105.2	5.2	13/10/39	0.01	17th	Recovered.
68	10/10/39	0.00025	4th	6th	105.2	5.2	13/10/39	0.01	16th	Recovered.
57	10/10/39	0.000025	3rd	6th	104.6	4.6	13/10/39	0.01	18th	Recovered.
66	10/10/39	0.000025	4th	6th	105.0	5.0	13/10/39	0.01	16th	Recovered.

Note.—The 16 buffaloes in Experiment 2, which received injections of dried goat spleen vaccine on the same day as the above animals, may be regarded as the "vaccine only" controls; and the 3 buffaloes in Experiment 2 (Nos. 61, 69 and 70) which received virulent cattle rinderpest virus, as the "virus only" controls to Experiment 4.

Section II.

Nutrition.

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Supplementation of Winter Grazing in the Transvaal with Special Reference to the Maintenance Protein Requirement of Sheep.

By D. B. SMUTS and J. S. C. MARAIS, Section of Nutrition,
Onderstepoort.

IN a previous paper (1940) it was shown that an acute protein deficiency exists in the natural grazing of the Transvaal and that this deficiency, which was shown not to be due to a difference in food intake during the different seasons, prevails for almost six months of the year. On the basis of the above results, it was further demonstrated that the magnitude of the protein deficiency is such that it necessitates a daily catabolism of tissue protein in order to provide for the inevitable nitrogenous losses associated with the protoplasmic activities constituting life. It is, therefore, conceivable that this condition of tissue catabolism operating over a considerable portion of the year may indeed be the primary if not the exclusive cause of the highly emaciated condition of stock during winter. In fact, according to the existing laws of nutrition, it seems impossible for any animal to maintain its normal intensity of tissue metabolism under a continual strain of protein shortage. The natural response under such conditions will in all probability be a reduction in intensity and rate of metabolism in order to conserve as much of its own tissues as possible. Such a state of affairs ultimately leads to a reduced vitality and consequently an increased susceptibility to disease from which large numbers of animals may indirectly succumb annually.

From the above consideration of existing conditions, it is evident that sheep husbandry can never, under the prevailing nutritional conditions, be established on a sound and permanent basis. Fortunately the condition is not beyond repair, since the only requirement is a judicious and economical method of supplementary winter feeding. Such a method of supplementation is simplified by the fact, that our national animal feed, namely maize, can be or is cultivated on nearly every farm and should therefore be available to serve as an excellent basic feed for winter feeding. On the other hand it is appreciated that the practical applicability of supplementary winter feeding is largely a matter of economics. It is, therefore, essential that the purpose and requirements of winter supplementation should be clearly understood. Thus it will be absolutely fallacious to try

SUPPLEMENTATION OF WINTER GRAZING.

and obtain any form of production, namely fattening, growth etc., during winter at the expense of supplementary feeding. Production should be attained exclusively during summer, when the natural food is plentiful and of a good nutritional value. Winter supplementation should have as its only object the prevention of tissue catabolism, i.e. the breakdown of tissue which has been synthesized during summer. For this reason it is of the utmost importance that only the minimum quantities of feed necessary to replenish the inevitable daily losses associated with the normal animal metabolism, should be fed. With this view in mind, the work to be reported on was conducted in order to obtain more information on the supplementary feeding value of some concentrates as well as the most efficient level at which they should be fed.

EXPERIMENTAL.

The original object was to conduct a series of supplementations on grazing cut during the months of April and July. Due to the fact that biological value determinations were also made on the same cuts there was not enough left to study the supplementary effect of a number of concentrates. Consequently only a few of the more practical feeding stuffs or combinations thereof were investigated. In order to augment this data a grass of more or less similar protein content as that of April was utilized for further supplementation studies. Five Merino wethers, previously used in the determination of the biological values of the grazing during the different seasons of the year, were utilized for these studies. They were therefore accustomed to the metabolism cages and this type of work. The grass, together with the supplementary feed were fed twice daily. Mineral supplementation was practised in all cases.

The metabolism cages were cleaned daily and the daily collection of faeces and urine aliquoted and stored over the 10 day collection period. At the end of the collection period the faeces were ground and representative samples taken for analysis. Representative samples of the composite 10 day urine and faecal aliquots were analyzed for total nitrogen. Prior to the collection period which lasted 10 days a preliminary period on the same ration and of the same duration was inserted.

EXPERIMENTAL RESULTS.

The results obtained from the various supplementations are summarized in Table 1. It will be noted that in the first investigation, April grazing of 0.73 per cent. nitrogen, which was previously shown (Smuts and Marais, 1940) to be inadequate in respect of protein for the maintenance of mature sheep, was supplemented by 5 grams of urea. By the addition of the latter substance the nitrogen intake was increased from approximately 3.6 grams to 6 grams with the result that a complete positive nitrogen balance was created. The biological value probably on account of the higher level of nitrogen intake is now reduced to 75 in comparison with 82 for the grazing alone. Both the apparent and true digestibilities are increased, the former to a greater extent than the latter. From these results it is clear that sheep can utilize urea nitrogen to

replenish the daily unavoidable nitrogenous losses associated with maintenance. This finding is in agreement with the hypothesis of Mitchell and Kendall, namely that the endogenous nitrogen is of a non-protein nitrogenous nature and can therefore be partially replaced by nitrogen of a non-protein nature. Thus it is not necessary in the utilization of such compounds as urea or ammonium salts by sheep for maintenance to assume that these compounds are necessarily transformed by micro-organisms into intact protein before it can actually be utilized by the system. In fact there exists ample evidence to support the view that no specific and selected combinations of amino acids are necessary for maintenance and that the endogenous nitrogen losses may, therefore, in all probability be directly satisfied by the simple nitrogenous compounds arising from the conversion of urea *in vivo*. When however the value of urea for growth purposes is to be assessed the position becomes quite different. To establish beyond doubt the growth-promoting value of urea, the basal ration should be complete but nitrogen free, so that the only source of nitrogen will be of urea origin. Otherwise the results will be ambiguous, since the effect observed may in reality be one of displacement rather than actual utilization, that is, the protein of the basal ration is simply displaced by urea for maintenance, and utilized for growth. The growth-promoting value of urea thus measured, is therefore not due to urea as such but to the protein contained in the basal ration. Hence any experiment, which neglects the above essentials, and claims that urea promotes growth, must be accepted with reserve, since the validity of the results is open to criticism.

In the second investigation July grazing containing 0.49 per cent. nitrogen was supplemented by 112 grams maize. As is clearly illustrated by the data, these sheep are in complete negative nitrogen balance. The utilization of the nitrogen contained in this supplementation is utilized extremely well as is indicated by the biological value of 85. The apparent digestibility is exceptionally low while the true digestibility, which takes into account the metabolic faecal nitrogen is 91 per cent. From the difference in apparent and true digestibility it is clear that the faecal nitrogen contains a high proportion of metabolic faecal nitrogen which is of endogenous nature, that is, the portion associated with the weight of the animal rather than with the dry matter consumption (Schneider, 1935). Of practical interest is the fact, that 112 grams of maize fed in conjunction with July grazing is insufficient to replenish the daily unavoidable nitrogenous losses of mature sheep. When the same grazing is supplemented with 56 grams of peanutmeal, the total nitrogen intake is raised to approximately 65 grams daily. From the metabolism results it is evident that notwithstanding the increase in protein intake there is still a considerable negative nitrogen balance. In fact, it appears from the figures that the magnitude of this negative nitrogen balance is greater than in the case of maize. From this it would appear either that peanut protein is not as efficiently utilized as that of maize or that portion of the protein is catabolized for energy purposes. The effect of both these metabolic reactions will result in a decrease in the biological value. The average biological value of 47 obtained for the peanut supplementation in comparison with the average

value of 75 obtained for the urea supplementation at approximately the same level of nitrogen intake, makes the second assumption of an energy deficiency the most probable. Under the conditions of the experiment sheep will naturally try to replenish both the unavoidable and inevitable nitrogen and energy losses associated with the minimum metabolism of the protoplasm from the experimental ration which is inadequate to meet these requirements. Consequently it is conceivable that under these circumstances only part of the requirements of each is met, causing a negative nitrogen balance to prevail. This argument is furthermore supported by the data obtained from the supplementation of 200 grams of straw with peanut meal in which the energy is supplied in the form of 200 grams of starch. In this case the total nitrogen intake arising mainly from the 32 grams of peanutmeal is only 3.38 grams. This nitrogen, now that the energy requirements are taken care of, is utilized with a 94 per cent efficiency against 47, when no starch is fed. This comparison again stresses the importance of eliminating all possible nutritional factors before the effect of one nutritional component can be systematically studied. Furthermore, it illustrates that the level of protein feeding under practical conditions is determined by the available energy.

In the fourth investigation grass of 0.81 per cent. nitrogen, equivalent in protein content to that of April grazing, was supplemented by only 60 grams of maize. The result, as will be seen from the figures, is that while the apparent digestibility is as low as 35 per cent., the nitrogen of the supplement ration is utilized with a 100 per cent. efficiency. In this supplementation the grass contributed the major portion of the total nitrogen intake and is, therefore, in all probability the reason for the low apparent digestibility. If, however, wheat straw with a lower nitrogen content than July grazing is supplemented by 150 grams maize and 100 grams starch, the biological value is decreased to 98 per cent., the apparent digestibility increased to 42 per cent. and a positive nitrogen balance is obtained. The result in comparison with the peanut supplementation of wheat straw, indicates that maize can be better utilized in practice for supplementary feeding purposes.

When grass of the same nitrogen content as was fed to mature sheep is now supplemented by 81 grams maize in case of young sheep, the total nitrogen intake is much less, due to the smaller consumption of grass. The ratio of grass protein to maize protein is much narrower as in the previous supplementation with mature sheep. Consequently the average apparent digestibility of 43 is higher, due to the higher proportion of better digestible maize protein. The absorbed nitrogen of this supplementation is utilized with a 100 per cent. efficiency so that these sheep are in a positive nitrogen balance. If now, however, half of the maize is displaced by an equivalent amount of peanutmeal, so that the total nitrogen intake is almost double that of the previous period, the approximate digestibility increases to 63, while the positive nitrogen balance remains more or less of the same magnitude. With a further increase in nitrogen intake by the addition of 80 grams peanutmeal instead of 40, the apparent digestibility increased further to 72 and the biological value decreased to an average value of 49. From this data it is clear that the level of protein feeding exerts a marked effect on the efficiency of utilization. Hence from

a practical point of view it is definitely uneconomical to feed in excess of the requirements of growing sheep since the extra growth obtained is not justified by the increase in feed expenditure. However, apart from the level of protein intake, it is quite possible that the constitution of the amino acid complex contained in the supplementation of grass, maize and peanut is not fully balanced in respect of the indispensable amino acids necessary for growth. That this is in reality the case is clearly demonstrated by a comparison of the biological values of the above supplements with that in the second last series of metabolism studies. In the latter case April grazing containing 0.77 per cent. N is supplemented by a mixture of maize and white fishmeal, so that the total nitrogen intake is approximately 18.5 grams. Hence the level of nitrogen intake is in excess of that of the peanut and maize supplementation. Nevertheless as will be seen from the data a biological value of 55 in comparison with 49 is obtained. This difference clearly illustrates that the amino acid composition in regard to the indispensable amino acids is superior for tissue synthesis in the first case. It is therefore clear that a maize and peanut supplementation of grazing is inferior to a maize and fishmeal supplementation. Interesting, however, are the data in the last investigation where less of the fishmeal protein and a larger proportion of the maize protein is included in the supplementation. Under these conditions even with a lower level of nitrogen intake the biological value drops from 55 to 48. A detailed study of the respective values indicates that the same if not a greater proportion of the absorbed nitrogen in the latter case has been catabolized. This in the face of the small positive nitrogen balance can only be explained by the fact, that a larger proportion of the available amino acids was catabolized probably on account of some indispensable amino acid deficiency.

It has already been established with rats that maize is deficient in lysine and tryptophane. Consequently the larger proportion of the inferior maize protein included in the second mixture may in all probability be the cause of the lower biological value and the poorer utilization of the mixed protein supplementation for synthetic purposes. However, for maintenance purposes maize is an excellent supplement, as is seen from the data in which 200 grams of wheat straw is supplemented by 150 grams of maize. The total nitrogen intake of 3.38 grams daily is utilized with a 98 per cent. efficiency so that sheep on this level of maize feeding, if the energy intake is sufficient, will be kept in positive nitrogen balance.

DISCUSSION.

A detailed survey of the entire data on the different supplementations as reported in this paper brings to light certain points of great interest in the practical application of winter supplementation. From this data it appears fairly definite that there also exists an energy deficiency in the protein deficient grazing. Hence July grazing supplemented by 56 grams peanutmeal shows a poorer biological value than the same grazing supplemented by 112 grams maize, which contains a greater supply of available energy. When however, peanutmeal, together with wheat straw is provided with additional energy in the form of 200 grams starch the biological value is almost

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of the same magnitude as that of maize at the same level of nitrogen intake. It is, therefore, clear that under practical conditions it will be futile to rectify the existing protein deficiency with a minimum quantity of protein unless the energy requirements are satisfied. For this reason maize, as is shown in the July grazing supplementation with 112 grams of maize, fulfils a dual purpose namely in providing at the same time both these deficient elements. Consequently maize must be looked upon as an ideal supplementary concentrate during the winter period.

Another fact of importance is that urea which is a non-protein nitrogenous compound can be utilized to supply the maintenance of nitrogen requirement of sheep. As has been shown in this investigation a positive nitrogen balance can be obtained when grazing of approximately 0.73 per cent. nitrogen is supplemented by 5 grams of urea. If therefore a cheap form of carbohydrates like molasses or starch can be economically procured, the maintenance requirement of energy and nitrogen can be satisfied by a suitable mixture of these materials with urea. Under our conditions there is, however, little chance of obtaining such cheap forms of carbohydrate. For this reason maize is indicated as the cheapest and most economical form of winter supplementation. From the data on the supplementation with growing sheep it appears as if maize is not fully balanced in respect to the indispensable amino acids and hence unable to promote tissue synthesis efficiently. It was however clearly indicated in the introductory remarks that the aim of winter supplementation should not be directed towards obtaining growth but merely as a precautionary measure in prohibiting catabolism of tissues synthesized during the summer. Consequently maize may also be successfully utilized with young stock in maintaining the integrity of their tissues.

SUMMARY AND CONCLUSIONS.

By means of metabolism experiments on mature and young sheep it was shown that approximately 81 grams of maize will supplement April grazing successfully in respect of protein if the energy requirements are satisfied. Due to the fact, that 150 grams maize efficiently supplement 200 grams of wheat straw with a lower nitrogen content than July grazing, it can be implied that it will also supplement July grazing successfully. Urea nitrogen has been shown to be utilized by sheep for maintenance purposes but must not be expected to promote growth unless experiments conducted under controlled conditions prove the contrary.

REFERENCES.

- MITCHELL, H. H., NEVENS, W. B., AND KENDALL, F. E. (1922). The relation between the endogenous catabolism and the non-protein constituents of the tissues. *J.B.C.*, Vol. 52, No. 2, p. 417.
- SMUTS, D. B., AND MARAIS, J. S. C. (1940). The utilization by sheep of the proteins contained in the natural grazing during the different seasons of the year. *Onderstepoort J. Vet. Sci. and An. Ind.* (in Press).
- SMUTS, D. B., AND MARAIS, J. S. C. (1939). The amino acid deficiencies of certain plant proteins. *Onderstepoort J. Vet. Sci. and An. Ind.* (in Press).
- SCHNEIDER, B. (1935). The subdivision of the metabolic nitrogen in the faeces of the rat, swine and man. *J.B.C.*, Vol. 109, No. 1.

TABLE 1.

*Supplementation of Grazing with Concentrates.**April Grazing (0.73 per cent. N) + 5 grams Urea.*

Animal No.	Average Wgt.	FOOD INTAKE.				Dry Matter Intake.	Nitrogen Intake.	Metabolic Faecal gen.	Absorbed Nitrogen.	Nitrogen in Urine.	Endogenous Nitrogen.	Food Nitrogen Retained.	Biological Value.	Nitrogen Balance.	Apparent Digestibility.	True Digestibility.
		Grazing.	Maize.	Peanut Meal.	Urea.											
38248	Kgm. 42	Grm. 500	—	Grm. —	Grm. 5	Grm. 455	Grm. 5.99	Grm. 2.94	Grm. 5.64	Grm. 2.57	Grm. 1.18	Grm. 4.25	75	0.48	51	94
49612	45	575	—	—	5	523	6.53	3.16	6.53	3.18	1.48	4.83	77	0.19	52	100
38252	40	476	—	—	5	433	5.81	3.02	4.74	2.57	1.07	3.24	68	0.22	48	82
38240	40	600	—	—	5	546	6.72	3.37	6.46	2.67	1.60	5.39	84	0.68	50	96
38249	39	325	—	—	5	296	4.75	2.12	4.58	2.22	1.09	3.45	75	0.41	55	97
											Average.....		75	—	51	94

July Grazing (0.49 per cent. N) + 112 grams Maize.

100	48	413	112	—	—	483	3.85	2.74	2.66	3.77	1.61	3.17	84	—0.50	29	98
101	43	150	112	—	—	241	2.57	1.72	1.21	2.06	1.44	1.65	80	—0.59	33	80
102	43	331	112	—	—	408	3.45	2.39	2.12	1.33	1.01	2.86	90	—0.27	31	92
103	45	306	112	—	—	385	3.33	2.28	2.31	3.33	1.61	2.93	88	—0.56	32	100
104	46	231	112	—	—	316	2.96	2.04	1.58	2.50	1.64	2.07	83	—0.72	31	84
											Average.....		85	—	31	91

July Grazing (0.49 per cent. N) + 56 grams Peanut Meal.

105	44	438	—	56	—	455	6.85	3.21	2.59	6.23	4.44	3.11	50	—0.80	53	91
106	44	385	—	56	—	406	6.59	3.14	2.64	6.09	4.56	2.98	49	—1.11	52	92
107	36	370	—	56	—	392	6.50	3.43	2.58	5.65	3.98	2.61	46	—0.91	47	87
108	40	438	—	56	—	455	6.85	3.36	2.59	6.08	4.65	2.87	47	—1.26	51	89
109	40	244	—	56	—	276	5.89	2.82	1.24	4.31	1.52	1.94	45	—0.82	52	73
											Average.....		47	—	51	96

TABLE 1—(continued).

Animal No.	Average Wgt.	FOOD INTAKE.				Dry Matter Intake.	Nitrogen Intake.	Metabolic Faecal Nitrogen.	Absorbed Nitrogen.	Nitrogen in Urine.	Endogenous Nitrogen.	Food Nitrogen Retained.	Biological Value.	Nitrogen Balance.	Apparent Digestibility.	True Digestibility.
		Grazing.	Maize.	Peanut Meal.	Urea.											
	Kgm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.				
21	38	540	60	—	—	559	5.34	2.63	4.66	1.48	1.67	4.66	100	0.55	38	87
22	48	520	60	—	—	540	5.20	2.75	4.69	1.55	1.77	4.69	100	0.39	37	90
23	37	520	60	—	—	540	5.20	2.48	4.03	1.49	1.59	4.03	100	0.06	30	78
													100	—	35	84
											Average.....					

Grass (0.81 per cent. N) + 81 grams Maize.

30	20	251	81	—	—	308	3.36	1.88	1.79	3.27	0.71	1.00	3.27	100	0.77	44	97	
31	20	318.	81	—	—	370	3.91	2.33	2.15	3.73	0.647	1.00	3.73	100.	0.93	40	95	
32	20	316	81	—	—	368	3.89	1.92	2.13	3.89	0.779	1.00	3.89	1000	1.19	51	100	
33	16	300	81	—	—	353	3.76	2.41	2.05	3.40	0.603	0.80	3.40	100	0.75	36	90	
Average,															100	—	43	96

TABLE 1—(continued).

Animal No.	Average Wgt.	FOOD INTAKE.			Dry Matter Intake.	Nitrogen Intake.	Nitrogen in Faeces.	Metabolic Faecal Nitrogen.	Absorbed Nitrogen.	Nitrogen in Urine.	Endogenous Nitrogen.	Food Nitrogen Retained.	Biological Value.	Nitrogen Balance.	Apparent Digestibility.	True Digestibility.
		Wheat Straw.	Maize.	Starch.												
	Kgm.	Gram.	Gram.	Gram.	Gram.	Gram.	Gram.	Gram.	Gram.	Gram.	Gram.	Gram.				
50	46	200	150	100	411	3.38	2.07	2.34	3.38	1.18	1.01	3.21	95	0.13	39	100
60	49	200	150	100	411	3.38	2.00	2.46	3.38	1.06	1.27	3.38	100	0.32	42	100
70	42	200	150	100	411	3.38	1.78	1.85	3.38	1.43	1.36	3.31	98	0.17	47	100
80	43	200	150	100	411	3.38	2.12	2.34	3.38	1.20	1.26	3.38	100	0.06	37	100
90	43	200	150	100	411	3.38	1.94	2.47	3.38	1.30	1.12	3.20	95	0.14	43	100
											Average.....		98	—	42	100

<i>Peanut.</i>																
		Peanut.														
51	51	200	32	200	410	3.54	2.55	2.25	3.24	1.37	1.07	2.94	91	-0.38	28	92
52	46	200	32	200	410	3.54	2.42	2.05	3.17	1.14	1.10	3.13	99	-0.02	32	90
53	46	200	32	200	410	3.54	2.51	2.13	3.16	1.49	1.15	2.82	89	-0.46	29	89
54	50	200	32	200	410	3.54	2.59	2.46	3.41	1.38	1.35	3.38	99	0.43	27	96
55	48	200	32	200	410	3.54	2.46	2.05	3.13	1.42	1.06	2.77	94	0.34	31	90
											Average.....		94	—	29	97

TABLE 1—(continued).
Grass 0-81 per cent. N + 40 grams Maize + 40 grams Peanut Meal.

Animal No.	Average Wgt.	FOOD INTAKE.			Dry Matter Intake.	Nitrogen in Intake.	Nitrogen in Faeces.	Metabolic Nitrogen.	Absorbed Nitrogen.	Nitrogen in Urine.	Endogenous Nitrogen.	Food Nitrogen Retained.	Biological Value.	Nitrogen Balance.	Apparent Digestibility.	True Digestibility.
		Grazing.	Maize.	Peanut Meal.												
35	Kgm. 25	Gram. 350	Gram. 40	Gram. 400	Gram. 6-84	Gram. 2-39	Gram. 2-32	Gram. 6-77	Gram. 6-72	Gram. 4-30	Gram. 1-30	Gram. 3-77	56	0-15	65	99
36	21	350	40	400	6-84	2-36	2-24	6-72	6-72	3-76	1-18	4-14	62	0-72	66	98
37	21	350	40	400	6-84	2-36	2-24	6-72	6-72	3-76	1-18	4-14	61	0-41	60	97
38	21	350	40	400	6-84	2-36	2-24	6-72	6-72	3-76	1-18	4-14	67	0-85	61	97
39	22	350	40	400	6-84	2-51	2-32	6-65	6-65	3-80	1-29	4-14	62	0-53	63	97
											Average.....		62	—	63	98

Grass (0-81 per cent. N) + 40 grams Maize + 80 grams Peanut.

40	22	350	40	447	10-19	2-52	2-30	10-17	10-17	5-87	0-92	5-22	51	1-80	75	100
41	25	350	40	447	10-19	3-06	2-77	9-90	9-90	5-83	1-13	4-70	47	0-80	70	97
42	25	350	40	447	10-19	3-05	2-68	9-82	9-82	5-83	1-15	4-08	52	1-26	70	96
43	26	350	40	447	10-19	3-05	2-68	9-82	9-82	6-79	1-35	4-38	45	0-35	72	98
44	21	350	40	447	10-19	2-75	2-58	10-02	10-02	5-90	1-09	5-21	52	1-54	73	99
											Average.....		49	—	72	96

April Grazing (0-77 per cent. N) + 200 grams Mixture 2.

16	33	MIXTURE 2. 500	—	—	18-51	3-34	3-27	18-44	18-44	9-22	1-65	10-87	59	5-95	82	99
17	30	500	—	—	18-51	3-79	3-27	17-99	17-99	9-22	1-50	10-27	57	5-50	80	97
18	26	500	—	—	18-51	4-10	3-27	17-68	17-68	9-26	1-45	9-37	53	4-65	78	96
19	32	500	—	—	18-51	3-50	3-27	18-28	18-28	9-28	1-50	10-50	52	5-73	81	99
20	32	395	—	—	17-64	3-57	2-77	16-84	16-84	8-94	1-60	9-50	56	5-13	84	95
											Average.....		55	—	87	97

April Grazing (0-77 per cent. N) + 200 grams Mixture 1.

22	27	MIXTURE 1. 500	—	—	16-67	3-96	3-27	15-98	15-98	8-99	1-35	8-34	46	3-72	76	96
23	27	500	—	—	16-67	3-98	3-27	15-96	15-96	10-34	1-35	6-97	44	2-35	76	96
24	27	500	—	—	16-67	3-77	3-27	16-77	16-77	8-10	1-35	9-42	58	4-80	77	97
25	27	500	—	—	16-67	3-90	3-27	16-04	16-04	9-67	1-25	7-62	48	3-10	77	96
26	30	500	—	—	16-67	4-35	3-27	15-59	15-59	10-56	1-50	6-53	42	1-76	74	94
											Average.....		48	—	76	96

MIXTURE (1)—		MIXTURE (2)—	
Maize meal.....	330	Maize meal.....	280
White fishmeal.....	150	White fishmeal.....	200

The Biological Value of the Proteins of Maize and Maize Supplemented with Lysine and Tryptophane.

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IN the continuation of our studies on the nutritive value of the different plant proteins, the proteins of maize were investigated by means of the Thomas-Mitchell method for determining the biological values of proteins.

As a feedingstuff maize occupies a unique position in this country in that it is the cheapest and most extensively grown animal feed, which provides both the nutritional elements now known to be seriously deficient in the natural pastures of the summer rainfall area during the winter seasons. Although maize is richest in carbohydrate and hence provides an excellent source of energy during winter supplementation, it has also been shown to provide sufficient protein for the maintenance requirements of animals when fed in the correct quantities. In maize, therefore, this country possesses a valuable animal feed which should be utilized to its fullest extent. It is, therefore, essential that a detailed knowledge about its nutritional qualities should be available. For this reason a special study has been undertaken to investigate the protein of maize in order to ascertain to what extent it can be utilized by the animal and which components limit its utilization so that, if possible, these deficiencies can be eliminated or rectified in practice by scientific supplementation.

According to Osborne and Mendel (1914) zein the most important of the maize proteins is deficient in the essential amino acids lysine and tryptophane. Zein supplemented with tryptophane is capable of supplying the maintenance requirements of rats, but growth can only take place after further supplementation with lysine. A similar deficiency has also been established by Hogan (1917) for the proteins of the whole maize. In these experiments conducted by him the protein intakes were not equalized. Thus it is difficult to assess the true value of these results. Nevertheless, the reactions on growth, after supplementing with these amino acids, were sharp enough to justify the given interpretation. The results of Hogan do not conform with those of Mitchell and Smuts (1932). According

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to the latter workers no supplementation occurred when tryptophane alone was added and only a slight improvement after lysine supplementation. A marked improvement was, however, obtained by supplementing with lysine and tryptophane simultaneously.

Notwithstanding these amino acid deficiencies of maize proteins Contesco and Rowan (1936) succeeded in keeping 4½ months old pigs in excellent condition on a maize ration without the occurrence of any signs of ill-health. An average daily gain of 0.417 Kg. per head was obtained. It is well known that the different proteins of the maize kernel supplement each other. The protein contained in the embryo improves that of the rest. For the whole maize a biological value of 69 has been determined by Laporta and co-workers (1937), whilst the biological value of the proteins without the embryo is only 50. Similarly maize supplemented by a gluten preparation gives excellent growth with young pigs according to Hart and McCollum (1914).

The biological values of maize, with rats as experimental animals, are, as reported by Mitchell (1924) at 5 and 10 per cent. proteins levels, 72 and 60 respectively. With pigs on a 5 per cent. level Mitchell and Kick (1927) found a value of 54, whilst Gaucher and Popov (1936) obtained a slightly lower value of 49. Boas Fixsen and Jackson (1932) experimenting with rats found a biological value of 67 for whole yellow maize at a 7.8 per cent. protein level. An exceptionally high biological value of 98 has been established by Smuts (1939) for sheep on a maintenance ration.

EXPERIMENTAL.

Rats were used as experimental animals. All determinations were carried out according to the method of Mitchell (1924). Only one biological value was determined on a series of six rats. The nitrogen low period was conducted either prior to or after the protein period. Six to seven day periods were allowed on a nitrogen low ration to establish constant nitrogen excretion. For the protein periods at least 10 days were allowed. Collection periods were of seven day's duration. Fe_2O_3 was used as faecal markers. The urine was collected in acid and the daily faeces digested by the Kjeldahl method. The week's digests of faeces were made up to volume and aliquots distilled for nitrogen determination. The urine collected over the period was made up to a known volume and aliquots analysed for nitrogen. The rations were made up so as to contain approximately 8 per cent. protein. The percentage composition of the different rations is tabulated in Table I. Analyses were made of all rations after careful mixing. To prevent deterioration, the rations were stored in an ice chest.

RESULTS.

The nitrogen metabolism data as well as the calculation of the biological values are given in Table II. The standardizing periods on the nitrogen low ration preceded the protein feeding periods in the three cases of yellow maize supplemented with lysine and tryptophane

separately and yellow maize supplemented with lysine and tryptophane simultaneously. For the yellow and white maize periods the nitrogen low period was conducted after the protein periods.

The calculation of the biological values is based on the principles as expounded by Mitchell (1924) namely that the metabolic faecal nitrogen is proportional to the dry matter intake and that the endogenous urinary nitrogen is proportional to the body weight.

TABLE I.
Percentage Composition of the Rations.

Ingredients.	N. Low.	Whole White Maize.	Whole Yellow Maize.	Whole Yellow Maize + Lysine.	Whole Yellow Maize + Tryptophane.	Whole Yellow Maize + Lysine + Tryptophane.
Whole white maize meal.....	—	81·6	—	—	—	—
Whole yellow maize meal.....	—	—	84·2	82·5	82·8	81·1
d-Lysine-di-hydrochloride.....	—	—	—	0·2	—	0·2
Tryptophane.....	—	—	—	—	0·15	0·15
Butter fat ⁽¹⁾	8·0	8·0	8·0	8·0	8·0	8·0
Cod liver oil.....	2·0	2·0	2·0	2·0	2·0	2·0
Sucrose.....	10·0	3·4	0·8	2·3	2·05	3·55
Harris' Vitamin B complex ⁽²⁾ ..	2·0	2·0	2·0	2·0	2·0	2·0
Salt mixture (Hubbel etc.) ⁽³⁾ ...	2·0	2·0	2·0	2·0	2·0	2·0
Whole egg white ⁽⁴⁾	3·8	—	—	—	—	—
NaCl.....	1·0	1·0	1·0	1·0	1·0	1·0
Agar.....	2·0	—	—	—	—	—
Starch (dextrinized).....	69·2	—	—	—	—	—
TOTAL.....	100·0	100·0	100·0	100·0	100·0	100·0
PERCENTAGE N.....	0·67	1·44	1·44	1·59	1·51	1·49

⁽¹⁾ The butter fat has been filtered through a coarse filter paper to remove any casein.

⁽²⁾ The Harris' Vitamin B complex is a preparation of "The Harris Laboratories", Tuckahoe, New York.

⁽³⁾ A new salt mixture described by Hubbel, R., Mendel, J. B. and Wakeman, A. J. (1937) *J. Nutr.* Vol. 14, pp. 273-285.

⁽⁴⁾ The whole egg white has been dried on a waterbath and extracted with ether.

As can be seen from these tables a significant difference is manifested between the biological values of whole white maize and whole yellow maize, the values being 76 ± 1.91 and 67 ± 0.98 . The difference of 10 ± 2.15 which gives a t value for $N \pm 10$ of 4.66 denotes a significant difference at $p \pm 0.001$. No significant difference is manifested between yellow maize and yellow maize supplemented separately with lysine and tryptophane. The biological values for the supplementations are 70 ± 2.63 and 66 ± 0.75 respectively. The differences are 3 ± 2.63 and 1 ± 1.23 , which gives t values for $n = 10$ of 1.14 and 0.81 respectively. These t values denote that the differences are insignificant. The simultaneous supplementation with the amino acids, however, enhanced the biological value to 81 ± 0.61 , which means a difference of 14 ± 1.15 and therefore a t value for $n = 10$ of 12.15 making this result highly significant at $p = 0.001$.

TABLE II.
Nitrogen Metabolism Data and the Calculation of the Biological Value.
 N—Low Period.

Rat No.	Initial Weight.	Final Weight.	Average Weight.	Daily Food Intake.	Daily N Intake.	Daily Faecal N.	Metabolic In.		Food N in Faeces.	Absorbed N.	Daily Urinary N.	Endogenous N.		Food in Urine.	Retained N.	N Balance.	Apparent Digestibility.	True Digestibility.	Biological Value.
							Per gm.	Per Day.				Per 100 gm Wt.	Per Day.						
WHOLE WHITE MAIZE PERIOD (1.44 PER CENT. N.)																			
1	179	185	182	14.1	—	49.6	3.52	—	—	—	—	23.6	13.0	—	—	—	—	—	—
2	210	210	210	12.3	—	36.2	2.94	—	—	—	—	23.6	13.0	—	—	—	—	—	—
3	157	155	156	10.7	—	34.4	3.21	—	—	—	—	24.0	15.4	—	—	—	—	—	—
4	170	174	172	11.1	—	36.4	3.28	—	—	—	—	20.8	12.1	—	—	—	—	—	—
5	149	150	150	11.9	—	37.8	3.18	—	—	—	—	24.8	16.5	—	—	—	—	—	—
6	164	160	162	12.1	—	41.4	3.42	—	—	—	—	27.6	17.0	—	—	—	—	—	—
N—Low Period.																			
3	218	216	217	14.3	—	49.8	3.48	—	—	—	30.8	14.2	—	—	—	—	—	—	—
4	156	160	158	12.9	—	44.2	3.43	—	—	—	21.2	13.4	—	—	—	—	—	—	—
5	181	188	185	14.6	—	48.4	3.32	—	—	—	30.0	16.2	—	—	—	—	—	—	—
6	188	190	189	12.6	—	44.0	3.49	—	—	—	30.4	16.1	—	—	—	—	—	—	—
7	196	196	197	13.3	—	41.4	3.11	—	—	—	28.8	14.6	—	—	—	—	—	—	—
8	147	149	148	12.4	—	45.6	3.68	—	—	—	32.4	21.9	—	—	—	—	—	—	—
— WHOLE YELLOW MAIZE PERIOD (1.44 PER CENT. N.)																			
3	200	216	208	18.1	260.6	49.6	3.48	63.0	—13.4	260.6	114.0	14.2	29.5	84.5	176.1	97.0	81	100	68
4	142	164	153	17.0	244.8	44.0	3.43	58.3	—14.3	244.8	104.8	13.4	20.5	84.3	160.5	96.0	82	100	66
5	170	194	182	18.1	260.6	38.4	3.32	60.1	—21.7	260.6	112.0	16.2	29.5	82.5	178.1	110.2	85	100	66
6	184	198	191	14.2	204.5	36.0	3.49	49.6	—13.6	204.5	106.4	16.1	30.8	75.6	128.9	62.1	82	100	63
7	185	201	193	18.1	260.6	40.8	3.11	56.3	—15.5	260.6	107.2	14.6	28.2	79.0	181.6	112.6	84	100	70
8	140	158	149	15.9	229.0	42.4	3.68	58.5	—16.1	229.0	106.0	21.9	32.6	73.4	155.6	80.6	81	100	68
																83	100	67	

TABLE 11 (a).
Nitrogen Metabolism Data and the Calculation of the Biological Value.
N-LOW PERIOD.

Rat No.	Initial Weight.	Final Weight.	Average Weight.	Daily Food Intake.	Daily N Intake.	Daily Faecal N.	Metabolic N.		Food N in Faeces.	Absorbed N.	Daily Urinary N.	Endogenous N.		Food in Urine.	Retained N.	N Balance.	Apparent Digestibility.	True Digestibility.	Biological Value.	
							Per gm.	Per Day.				Per 100 gm.	Per Day.							
WHOLE YELLOW MAIZE \pm 0.25 PER CENT. D-LYSINE-DI-HYDROCHLORIDE PERIOD (1.59 PER CENT. N.)																				
1	96	93	95	6.2	—	22.0	3.55	—	—	—	16.0	16.8	—	—	—	—	—	—	—	
2	93	92	93	6.5	—	17.3	2.66	—	—	—	16.9	18.2	—	—	—	—	—	—	—	
3	98	95	97	5.1	—	20.2	3.95	—	—	—	12.8	13.2	—	—	—	—	—	—	—	
4	90	87	89	7.1	—	26.4	3.72	—	—	—	11.9	13.4	—	—	—	—	—	—	—	
5	96	95	96	6.5	—	23.9	3.68	—	—	—	14.0	14.6	—	—	—	—	—	—	—	
6	103	102	103	6.7	—	23.1	3.45	—	—	—	19.4	18.8	—	—	—	—	—	—	—	
N-LOW PERIOD.																				
1	105	107	106	6.0	95.4	16.5	3.55	21.3	—	4.8	95.4	39.1	16.8	17.8	21.3	74.1	39.8	83	100	78
2	90	100	95	6.1	97.0	16.9	2.66	16.2	0.7	96.3	47.4	18.2	17.3	13.6	30.1	66.2	32.7	83	99	69
3	98	107	103	6.6	104.9	16.1	3.96	26.1	10.0	104.9	53.6	13.2	13.6	40.0	64.9	35.2	85	100	62	72
4	99	104	102	7.3	116.1	16.9	3.72	27.2	10.3	116.1	44.5	13.4	13.7	30.8	85.3	54.7	85	100	72	72
5	109	117	113	7.4	117.7	22.2	3.68	27.2	5.0	117.7	49.4	14.6	16.5	33.9	84.8	46.1	81	100	72	64
6	90	98	94	7.1	112.9	17.3	3.45	24.5	7.2	112.9	58.9	18.8	17.7	41.2	71.7	36.7	85	100	64	64
																	84	100	70	
WHOLE YELLOW MAIZE \pm 0.15 PER CENT. TRYPTOPHAN PERIOD (1.51 PER CENT. N.)																				
3	123	118	121	7.9	—	34.8	4.41	—	—	—	18.4	15.2	—	—	—	—	—	—	—	—
4	112	113	113	7.5	—	27.2	3.63	—	—	—	13.6	12.0	—	—	—	—	—	—	—	—
5	115	104	110	6.7	—	27.2	4.06	—	—	—	26.6	24.2	—	—	—	—	—	—	—	—
6	112	109	111	6.9	—	28.0	4.06	—	—	—	17.6	15.9	—	—	—	—	—	—	—	—
7	108	108	108	7.5	—	29.6	3.95	—	—	—	18.4	17.0	—	—	—	—	—	—	—	—
8	112	114	113	7.5	—	29.2	3.89	—	—	—	14.4	12.7	—	—	—	—	—	—	—	—
WHOLE YELLOW MAIZE \pm 0.15 PER CENT. TRYPTOPHAN PERIOD (1.51 PER CENT. N.)																				
3	131	142	137	11.4	172.1	32.0	4.41	50.3	—	18.3	172.1	81.5	15.2	20.8	60.7	111.4	58.6	81	100	65
4	120	130	125	8.8	132.9	22.4	3.63	31.9	9.5	132.9	61.9	12.0	15.0	46.9	86.0	48.6	83	100	65	65
5	112	125	119	10.2	154.0	25.6	4.06	41.4	15.8	154.0	78.6	24.2	28.8	49.8	104.2	49.8	83	100	68	68
6	114	122	118	7.2	108.7	17.6	4.06	29.2	11.6	108.7	53.0	15.9	18.8	34.2	74.5	38.1	84	100	69	69
7	111	123	117	8.1	122.3	18.0	3.95	32.0	14.0	122.3	62.2	17.0	19.9	42.3	80.0	42.1	85	100	65	65
8	118	124	1.1	7.9	119.3	20.0	3.89	30.7	10.7	119.3	57.2	12.7	15.4	41.8	77.5	42.1	83	100	65	65
																	83	100	66	

TABLE II (b).
Nitrogen Metabolism Data and the Calculation of the Biological Value.

N-LOW PERIOD.

Rat No.	Initial Weight.	Final Weight.	Average Weight.	Daily Food Intake.	Daily N Intake.	Daily Faecal N.	Metabolic N.		Food N in Faeces.	Absorbed N.	Daily Urinary N.	Endogenous N.		Food in Urine.	Retained N.	N Balance.	Apparent Digestibility.	True Digestibility.	Biological Value.
							Per gm. Food.	Per Day.				Per 100 gm. Wt.	Per Day.						
WHOLE YELLOW MAIZE \pm 0.2 PER CENT. D-LYSINE-DI-HYDROCHLORIDE + 0.15 PER CENT. TRYPTOPHANE PERIOD (1.49 PER CENT. N.)																			
19	132	152	142	12.4	184.8	30.0	3.83	47.5	-17.5	184.8	55.0	11.5	16.3	38.7	146.1	+99.8	84	100	79
20	123	142	133	10.6	157.9	25.2	3.69	39.1	-13.9	157.9	51.5	14.9	19.8	31.7	126.2	+79.2	84	100	80
21	121	141	131	11.4	169.9	30.4	3.94	44.9	-14.5	169.9	57.4	19.0	24.9	32.5	137.4	+82.1	82	100	81
22	121	142	132	11.0	163.9	26.8	3.81	41.9	-15.1	163.9	46.6	13.5	17.8	28.8	135.1	+90.5	84	100	82
23	114	135	125	10.6	157.9	27.6	4.18	44.3	-16.7	157.9	49.4	13.3	16.6	32.8	125.1	+80.9	83	100	79
24	108	121	115	8.5	126.7	20.0	4.00	34.0	-14.0	126.7	40.0	15.1	17.4	22.6	104.1	+66.1	84	100	82
																	84	100	81

From the statistical analysis of these results it is clear that the protein of whole white maize is significantly superior to that of whole yellow maize. This difference was rather unexpected, and can at present only be explained by a constitutional difference in the protein moiety of different strains or varieties of maize. This point can, however, only be settled by direct experimentation on this aspect.

It is further also clear that the supplementation with lysine and tryptophane does not affect the utilization of the nitrogen contained in maize, while the simultaneous supplementation of lysine and tryptophane causes a marked increase in the nitrogen utilization of the proteins of yellow maize.

These results on the supplementary effect of the amino acids on the proteins of maize as measured by the nitrogen utilization are in accordance with the results obtained by Mitchell and Smuts (1932) with the paired feeding technique. It will be noted that in this study only a slight increase of 3 ± 2.63 is obtained by the lysine supplementation. This small difference falls within the experimental error. This observation is, therefore, not in accordance with the findings of Mitchell and Smuts by means of the paired feeding test. It must, therefore, be assumed that the slight though insignificant increase in nitrogen utilization after the lysine addendum may in all probability become significant if the number of determinations is increased and hence verify the indications obtained that lysine supplementation only brings about a limited improvement in the utilization of the maize proteins.

CONCLUSIONS.

1. The biological values of whole white maize and whole yellow maize are 76 ± 1.91 and 67 ± 0.98 at approximately 8 per cent. protein level.
2. The proteins of white maize are significantly better than that of yellow maize.
3. Supplementation with lysine and tryptophane separately does not increase the nitrogen utilization of yellow maize to any marked extent.
4. Supplementation with lysine and tryptophane simultaneously markedly increases the nitrogen utilization of the yellow maize protein.

REFERENCES.

- BOAS FIXSEN, M. A., AND JACKSON, H. M. (1932). The biological values of proteins IV. The biological values of the proteins of wheat, maize and milk. *Biochem. J.*, Vol. 26, p. 1923.
- CONTESCO, D., AND ROWAN, G. (1936). Valuer du maïs comme constituant exclusif de l'alimentation des jeunes porcs. *Ann. Inst. Nat. Zootec. Roumanie*, Vol. 5, pp. 106-113.
- GAUCHER, G., AND POPOV, I. D. (1936). The biological value of some protein feeds used in Bulgaria. *Ann. Univ. Sofia 5. Fac. Agron. Sylvicult.*, Vol. 14, p. 209-238.

BIOLOGICAL VALUE OF PROTEINS.

- HART, E.B., AND McCOLLUM, E. V. (1914). Influence on growth of rations restricted to the corn or wheat grain. *J. Biol. Chem.*, Vol. 19, p. 373.
- HOGAN, A. G. (1917). Corn as a source of protein and ash for growing animals. *J. Biol. Chem.*, Vol. 29, p. 485.
- LAPORTA, M., BUX, G., AND PICCOLI, R. (1937). Valore integrativo delle proteine del germe de zea mais e di Vicia faba. *Quad. Nutrizione*, Vol. 4, pp. 453-466.
- MITCHELL, H. H. (1924). A method of determining the biological value of protein. *J. Biol. Chem.*, Vol. 58, pp. 873-903.
- MITCHELL, H. H. (1924). The biological values of proteins at different levels of intake. *J. Biol. Chem.*, Vol. 58, pp. 905-925.
- MITCHELL, H. H., AND KICK, C. H. (1927). The supplementary relation between the proteins of corn and of tankage determined by metabolism experiments on swine. *J. Agric. Res.*, Vol. 35, p. 857.
- MITCHELL, H. H., AND SMUTS, D. B. (1932). The amino acid deficiencies of beef, wheat, corn, oats and soyabeans for growth in the white rat. *J. Biol. Chem.*, Vol. 95, pp. 263-281.
- OSBORNE, T. B., AND MENDEL, L. B. (1914). Amino acids in nutrition and growth. *J. Biol. Chem.*, Vol. 18, p. 1.
- SMUTS, D. B. (1939). Die Eiwitgehalte van Transvaalse weiding met spesiale verwysing na die onderhoudseiwitbenodighede van skape. Tesis, Universiteit van Pretoria, Okt., 1939.

The Biological Values of the Proteins of Oats, Barley, Wheatbran and Pollard.

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THE value of cereals in human and animal nutrition is fully recognized and appreciated. In fact it has become a regular and prominent portion of the daily dietaries of man and an inseparable portion in the balanced rations of stock.

Similarly its by-products have through years of experience attained an increasing popularity in the nutrition of farm animals. Lately the value of wheaten bran as a natural means of stimulating peristalsis in human beings has been recorded. Although these products as a group are not high in protein and therefore generally regarded as energy producing nutrients, they nevertheless contribute a fair quantity of protein to the daily aggregate of protein intake of both man and stock. It is consequently of importance that a detailed knowledge about the constitution and availability of the proteins contained in cereals and their by-products should be available, in order to assess their true nutritional value and to supplement in a practical way the indispensable amino acids which may be deficient. For this reason the above cereals and by-products were investigated by means of the Thomas-Mitchell nitrogen balance method for the estimation of their respective biological values.

In determinations on the biological values of proteins at different levels of protein intake Mitchell (1924) obtained values of 79 and 65 for oats at 5 and 10 per cent. protein levels. Smuts and Malan (1938) determined the biological value for rolled breakfast oats at 8 per cent. level as being 84, which is very near the value of 83 for pre-cooked oatmeal as determined by Murlin and Mattill (1938). In a comparison between barley and oats Osborne and Mendel (1920) could not assign any difference in the nutritive value between the two proteins. Neither oats nor barley can meet the growth requirements according to Steenbock and Gross (1918). Similar are the results of Hughes (1937) namely that barley as the only source of protein in the ration of pigs allows only slow growth, with a high food intake per unit bodyweight increase. For wheatbran and barley Gaucher and Popov (1936) determined the biological values 82 and 62 respectively. The proteins of bran and of the embryo are superior

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to that of the endosperm according to Johns and Finks (1920), Osborne and Mendel (1919) and Boas Fixsen and Jackson (1932). A rather low biological value of 57 has been determined by Klein and co-workers (1926) for wheatbran, whilst Wan (1935) determined the much higher value of 72. Excellent growth and reproduction were observed on rats with treated and untreated wheatbran.

EXPERIMENTAL.

In principle the method described by Mitchell (1924) has been adopted. Male rats of 100-150 grams were used. It was found that the larger rats gave less trouble as regards food consumption and thereby the danger of any tissue breakdown that may be caused by insufficient energy intake was greatly minimised. Only one biological value was determined on a series of six rats. The nitrogen low period was conducted either prior to or after the protein periods. Six to seven day periods were allowed on a nitrogen low ration to establish constant nitrogen excretion. For the protein periods at least 10 days were allowed. The collection periods were of seven days' duration. The urine was collected in acid and the daily faeces digested by the Kjeldahl method. To distinguish between faeces of the preliminary periods and collection periods Fe_2O_3 was used as a marker. At the end of the collection period the week's digests of faeces were made up to volume and aliquots distilled for nitrogen determination. The urine collected over the period was made up to a known volume and aliquots digested for nitrogen determination. The rations were made up so as to contain approximately 8 per cent. protein. The composition of the rations are given in Table 1. All the rations were analysed for nitrogen. To prevent deterioration the rations were kept in an ice chest.

RESULTS.

The nitrogen metabolism data as well as the calculations of the biological values are given in Table II. The standardizing periods on the nitrogen low ration preceded the protein periods in the cases of oats and barley and followed the protein periods directly again in the cases of wheatbran and pollard.

As can be seen from these results the biological values for oats, barley, wheatbran and pollard are 83 ± 2.04 , 77 ± 1.98 , 74 ± 2.82 and 84 ± 1.66 respectively. These biological values differ only slightly from the figures expressing the percentage utilizable protein which are 79 ± 2.73 , 68 ± 2.52 , 72 ± 2.82 and 83 ± 1.44 for oats, barley, wheatbran and pollard respectively. These small differences are due to the high digestibilities of the proteins. The digestibilities as determined are 95 ± 1.25 , 89 ± 1.51 , 98 ± 1.44 and 99 ± 0.82 for oats, barley, wheatbran and pollard respectively.

It is obvious from these results that these proteins are fairly well balanced and that they differ only slightly in their nutritive value; barley being the poorest and pollard the best. The explanation for the fact that pollard is better than wheatbran must be sought in the supplementary effect of the endosperm and epidermis of the wheat kernel, as pollard contains a higher percentage endosperm than wheatbran.

SUMMARY.

The biological values and digestibilities of the proteins of whole oats seed, unpearled barley, wheathran and pollard have been determined and a figure expressing the percentage utilizable protein calculated.

TABLE 1.
Percentage Compositions of Rations.

Ingredients.	N Low.	Oats Seed.	Barley.	Wheat Bran.	Pollard.
Whole oats seed.....	—	69.6	—	—	—
Whole barley.....	—	—	82.5	—	—
Wheat bran.....	—	—	—	69.6	—
Pollard.....	—	—	—	—	45.5
Butterfat ⁽¹⁾	8.0	8.0	8.0	8.0	8.0
Cod liver oil.....	2.0	2.0	2.0	2.0	2.0
Sucrose.....	10.0	10.0	2.5	10.0	10.0
Harris yeast ⁽²⁾	2.0	2.0	2.0	2.0	2.0
Salt mixture ⁽³⁾	2.0	2.0	2.0	2.0	2.0
Whole egg ⁽⁴⁾	3.8	—	—	—	—
NaCl.....	1.0	1.0	1.0	1.0	1.0
Agar.....	2.0	—	—	—	—
Starch (dextrinized).....	69.2	5.4	—	5.4	29.5
TOTAL.....	100.0	100.0	100.0	100.0	100.0
PERCENTAGE N.....	0.64	1.46	1.59	1.56	1.58

(¹) The butter fat has been filtered through a coarse filter paper to remove casein.

(²) Vitamin B. preparation prepared by "The Harris Laboratories", Fuckahoe, New York.

(³) A new salt mixture described by Hubbel, R., Mendel, J. B. and Wakeman, A. J. (1937), *J. Nutr.* Vol. 14, pp. 273-285.

(⁴) The whole egg has been dried on a waterbath and extracted with ether.

REFERENCES.

- BOAS FIXSEN, M. A., AND JACKSON, H. M. (1932). The biological values of protein. IV. The biological values of the proteins of wheat, maize and milk. *Biochem. J.*, Vol. 26, p. 1923.
- GAUCHER, G., AND POPOV, I. D. (1936). The biological value of some protein feeds used in Bulgaria. *Ann. Univ. Sofia, 5, Fac. Agron. Sylvicult*, Vol. 14, pp. 209-238.
- HUGHES, E. H. (1937). Biological value of casein as a supplement to the protein of barley in rations for pigs. *J. Agric. Res.*, Vol. 55, pp. 461-465.
- JOHNS, C. O., AND FINKS, A. J. (1920). Studies in nutrition. VI. The nutritive value of peanut flour as a supplement to wheat flour. *J. Biol. Chem.*, Vol. 42, p. 569.
- KLEIN, A., HARROW, B., PINE, L., AND FUNK, C. (1926). The nutritive value of various layers of the wheat and corn kernel. *Amer. J. Physiol.*, Vol. 76, p. 237.

BIOLOGICAL VALUES OF PROTEINS.

- MITCHELL, H. H. (1924). A method of determining the biological value of protein. *J. Biol., Chem.*, Vol. 58, p. 873-903.
- MITCHELL, H. H. (1924). The biological values of proteins at different levels of intake. *J. Biol. Chem.*, Vol. 58, pp. 905-925.
- MURLIN, J. R., AND MATTILL, H. A. (1938). Digestibility and nutritional value of cereal proteins in the human subject. *J. Nutr.*, Vol. 16, pp. 15-33.
- OSBORNE, T. B., AND MENDEL, L. B. (1919). The nutritive value of the wheat kernel and its milling products. *J. Biol. Chem.*, Vol. 37, p. 557.
- OSBORNE, T. B., AND MENDEL, L. B. (1920). Nutritive value of the proteins of the barley, oats, rye and wheat kernels. *J. Biol. Chem.*, Vol. 41, p. 275.
- SMUTS, D. B., AND MALAN, A. I. (1938). Plant Proteins II. The biological values of lucernemeal, sesamemeal, peanutmeal, coprameal, cottonseed-meal and oatmeal. *Onderstepoort J. Vet. Sci. and Animal Industry*, Vol. 10, pp. 207-219.
- STEENBOCK, H., AND GROSS, E. G. (1918). Dietary qualities of barley. *J. Biol. Chem.*, Vol. 35, pp. 62-74.
- WAN, . (1935). The biological value of proteins and the digestibility of food constituents of mixed vegetarian diets containing processed wheat brans. *Chinese J. Physiol.*, Vol. 9, pp. 125-140.

TABLE 2.
Nitrogen Metabolism Data and the Calculation of the Biological Value.
N-Low Period.

Rat No.	Initial Wgt.	Final Wgt.	Average Wgt.	Daily Food Intake.	Daily N Intake.	Daily Faecal N.	Metabolic N.		Food N in Faeces.	Absorbed N.	Daily Urinary N.	Endogenous N.		Food N in Urine.	N Retained.	N Balance.	Apparent Digestibility.	True Digestibility.	Biological Value.	Per cent. utilisable Protein.
							Per Gram Food.	Per Day.				Per 100 Gram Wgt.	Per Day.							
Whole Oats Seed Period (1.46 per cent. N).																				
7	120	139	139	10.4	151.8	51.6	3.70	38.5	13.1	138.7	43.2	15.4	21.4	21.8	116.9	+57.0	66	91	84	76
8	144	179	178	11.7	170.8	46.8	3.36	39.3	7.5	163.3	66.4	15.3	27.2	39.2	124.1	+57.6	73	96	76	73
9	160	198	194	11.6	173.7	37.4	3.29	31.5	5.9	167.8	48.4	18.9	31.0	35.4	129.7	+59.8	75	97	91	88
10	143	150	146	12.1	158.7	39.4	3.49	41.5	4.7	150.1	51.6	14.8	22.2	29.4	120.7	+62.6	74	97	80	78
11	130	143	138	12.1	158.7	37.4	3.32	40.2	7.2	169.5	47.2	15.0	20.3	26.9	142.6	+82.1	73	96	84	81
12	152	160	156	12.7	185.4	55.8	3.13	39.8	16.0	169.4	50.4	14.5	22.6	27.8	141.6	+79.2	70	91	83	79
N-Low Period.																				
7	140	138	139	9.3	—	35.8	3.85	—	—	—	21.6	15.5	—	—	—	—	—	—	—	—
8	137	135	136	8.9	—	33.0	3.71	—	—	—	20.0	14.7	—	—	—	—	—	—	—	—
9	138	140	139	8.7	—	30.2	3.47	—	—	—	19.2	13.8	—	—	—	—	—	—	—	—
10	132	134	133	8.8	—	34.4	3.91	—	—	—	18.4	13.8	—	—	—	—	—	—	—	—
11	142	144	143	9.9	—	38.2	3.86	—	—	—	17.6	12.3	—	—	—	—	—	—	—	—
12	127	132	130	9.6	—	34.1	3.55	—	—	—	19.6	15.1	—	—	—	—	—	—	—	—
Whole Barley Period (1.59 per cent. N).																				
7	125	155	140	16.3	259.2	82.4	3.85	62.7	19.7	239.5	73.6	15.5	21.7	51.9	187.6	+103.2	68	92	78	72
8	124	150	137	15.9	252.8	87.2	3.71	59.0	28.2	224.6	81.6	14.7	20.1	61.5	163.1	+84.0	68	89	73	65
9	130	158	144	15.4	244.9	79.2	3.47	53.4	25.8	219.1	70.4	13.8	19.9	50.5	168.6	+95.3	68	89	77	69
10	120	142	131	13.6	216.2	69.6	3.91	53.2	16.4	199.8	72.0	13.8	18.1	53.9	145.9	+64.6	68	92	73	67
11	140	156	148	14.6	252.1	82.4	3.86	56.4	26.0	206.1	53.6	12.3	18.2	35.4	170.7	+96.1	64	89	83	74
12	120	136	128	14.2	225.8	88.8	3.55	50.4	38.4	187.4	64.0	15.1	19.3	44.7	142.7	+73.0	61	83	76	63
																	66	89	77	68

TABLE 2—(continued).
Nitrogen Metabolism Data and the Calculation of the Biological Value.
N-Low Period.

Rat No.	Initial Wgt.	Final Wgt.	Average Wgt.	Daily Food Intake.	Daily Faecal N.	Metabolic N.		Food N in Faeces.	Absorbed N.	Daily Urinary N.	Endogenous N.		Food N in Urine.	N Retained.	N Balance.	Apparent Digestibility.	Biological Value.	Percentage utilizable Protein.
						Per Gram Food.	Per Day.				Per 100 Gram Wgt.	Per Day.						
13	129	130	130	10.2	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	—	—	—
14	126	130	128	8.4	36.6	3.59	15.2	—	17.2	19.2	15.2	—	—	—	—	—	—	—
15	125	145	135	13.9	28.8	3.43	15.3	—	19.6	15.3	—	—	—	—	—	—	—	—
16	127	155	141	16.0	36.0	2.95	20.0	—	28.8	20.0	—	—	—	—	—	—	—	—
17	130	129	130	7.5	31.8	3.79	20.0	—	26.4	14.2	—	—	—	—	—	—	—	—
18	125	125	125	10.3	27.2	3.63	11.8	—	18.4	14.2	—	—	—	—	—	—	—	—
					37.8	3.67	11.8	—	14.8	—	—	—	—	—	—	—	—	—
Wheatbran Period (1.56 per cent. N).																		
1	122	140	131	13.8	215.3	49.5	0.1	215.2	70.4	13.2	17.3	53.1	162.1	95.3	77	100	75	75
14	118	136	127	12.7	198.1	46.4	2.8	195.3	82.4	15.3	19.4	63.0	132.3	69.3	77	99	68	67
15	125	145	135	13.9	216.8	60.0	2.95	213.8	74.4	20.0	27.0	47.4	150.4	82.4	72	91	76	69
16	127	155	141	16.0	249.6	68.0	7.4	242.2	70.4	18.9	26.6	43.8	198.4	111.2	73	97	82	80
17	116	130	123	11.7	182.5	44.8	2.3	180.2	72.8	14.2	17.5	55.3	142.9	64.9	75	99	69	68
18	110	122	116	10.5	163.8	38.4	—0.1	163.8	58.4	11.8	13.7	44.7	119.1	67.0	77	100	73	73
						3.67	38.5	—	—	—	—	—	—	—	75	98	74	72
N-Low Period.																		
19	118	116	117	9.3	—	39.3	4.23	—	—	17.6	15.0	—	—	—	—	—	—	—
20	113	115	114	9.7	—	29.0	2.99	—	—	23.6	20.7	—	—	—	—	—	—	—
21	114	110	112	7.7	—	26.6	3.45	—	—	19.2	17.1	—	—	—	—	—	—	—
22	135	139	137	10.0	—	36.4	3.64	—	—	12.4	9.1	—	—	—	—	—	—	—
23	129	129	129	9.3	—	37.2	4.00	—	—	21.6	16.7	—	—	—	—	—	—	—
24	145	149	147	10.8	—	41.8	3.87	—	—	22.4	15.2	—	—	—	—	—	—	—
Pollard Period (1.58 per cent. N).																		
19	121	121	121	13.2	208.6	55.2	4.23	—	—	51.2	15.0	18.2	33.0	175.6	102.2	74	100	84
20	109	119	114	9.8	154.8	37.6	2.99	29.3	8.3	45.6	40.8	17.2	129.3	76.4	76	95	88	84
21	105	121	113	11.4	180.1	41.6	3.45	39.3	2.3	177.8	55.2	20.7	139.3	83.3	77	99	80	79
22	123	144	134	13.0	205.4	48.0	3.64	47.3	0.7	204.6	38.2	9.1	12.2	178.6	119.2	77	100	87
23	129	143	136	12.2	192.8	46.4	4.00	48.8	—2.4	192.8	60.8	16.7	38.1	154.7	85.6	76	100	80
24	135	160	148	15.3	241.7	57.6	3.87	59.2	—1.6	241.8	15.2	22.5	39.9	201.9	121.7	76	100	83
															76	99	84	83

The Utilization of the Protein of Somerset Beans by Rats and Sheep.

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EXPERIENCE and practical results have demonstrated beyond doubt that the future of Animal Production in South Africa is largely predetermined by the amount and type of available nutritious feeds during those seasons of the year, when the natural flora has deteriorated to such an extent that it becomes nutritionally inadequate to maintain animals subsisting solely on it. The problem of national importance arising from this complex situation, resolves itself, therefore, primarily into devising means and ways by which adequate amounts of feed can be ensured during those periods when supplementary feeding becomes absolutely essential. Unfortunately climatic conditions prevailing in the larger portions of the animal production areas do not favour extensive production of home-grown fodder during winter. Except in rare and fortunate cases where irrigation may be executed farmers have to rely almost exclusively for winter feeding on such amounts of feed which could be conserved during, and carried over from the preceding summer. This highly essential practice of food conservation is, however, not yet fully appreciated in practice, so that in many instances either no effort is made to conserve feed or inadequate amounts are conserved which becomes exhausted early in winter. This precarious position coupled with unreliable summer rainfall conditions, as well as the great bulk of plant material required to ensure adequate reservation of feed during winter make it highly debatable whether it would not be far more practical and economical to adopt the principle of concentrate supplementation. In fact, it has been shown in a previous publication that our national feed namely, maize, is particularly suitable for such a purpose and when the condition arises it may be scientifically supplemented with other available protein feeds to make a complete balanced ration for any specific animal function. However, at present every progressive farmer is endeavouring in his own way to combat this evil of winter feeding, and a variety of individual methods are in existence.

UTILIZATION OF THE PROTEIN OF SOMERSET BEANS.

During the summer months of 1938 one of the authors (J.C.B.) visited several cattle ranches in the Northern Transvaal. On one of these ranches at Bandolierskop, he was struck by the abundant vegetative growth of a type of velvet bean.

He was informed that these beans came from Southern Rhodesia and that the seed was mixed with sunflower seed; the result was that the vines which often attain a length of 20 yards or more grew over the sunflower stems. (Figure 1.)

These beans were later identified as a velvet bean (*Stizolobeum*) called Somerset beans.

According to information obtained from Mr. D. E. McLoughlin, Agriculturist, Southern Rhodesia, this variety of velvet bean was introduced from India in 1926, and it soon proved to be superior to any which had previously been grown in the Colony.

In trials at the Salisbury Agricultural Experiment Station during 1927-1929 the following yields were obtained per acre, viz., green fodder 25,497 lb., hay 4,793 lb., seed 2,690 lb. The Experiment Farm, University of Pretoria, obtained a yield of 4,301.8 lb. of hay per acre in the first trial in 1939. A farmer in Northern Transvaal reported a yield of over 4,000 lb. of seed per acre.

It appears that in Southern Rhodesia the Somerset variety is practically the only variety of velvet bean grown in the colony, where it is used chiefly as a hay or silage crop.

In the Northern Transvaal, farmers allow the crop to mature. The whole plant is then ground, in a hammermill and molasses added. This feed is well liked by cattle and very good results have been observed when the hammermilled Somerset beans sprayed with molasses have been fed to cattle.

Because of this apparent nutritive value and the high yields of hay and beans, it was decided to undertake certain protein studies on these beans.

DESCRIPTION.

It would be of interest to describe the Somerset bean briefly and to mention important facts of practical interest to the grower or farmer.

The Somerset bean is a vigorously growing annual, which requires a long growing season.

Under favourable conditions the vines may attain a length of 20 yards or more.

The leaves are trifoliate, the leaflets are entirely ovate, with laterals oblique, acuminate and pubescent on the lower side. (Figure 2.)

The flowers, which are papilionaceous, are dark purple, 15 to 30 being produced on a long pendent branched raceme in groups of 3-5 on short lateral branchlets. (Figure 3.)

There are from 10 to 30 pods on a lateral branch; the former are pubescent when immature. (Figure 4.)

The mature pods are smooth, $5\frac{1}{2}$ inches long, with one twist; they are longitudinally ridged. There are usually from 5 to 8 oval, smooth, black marbled seeds in each pod. (Figure 5.)

PLANTING.

As the Somerset bean requires a long growing season, planting should take place early in the spring. The mealie planter can be used but the holes in the discs should be made larger in order to enable the beans to pass through.

This crop is usually planted 3-4 inches deep in rows 36-40 inches apart with 18 inches between plants in the rows.

A supporting crop, such as sunflowers, increases the yield of seed of Somerset beans. The sunflowers should be sown in the same rows as the beans and about 3-4 feet apart.

HARVESTING.

If the crop is harvested with the object of grinding the whole plant in a hammermill, it should be allowed to mature. Harvesting is carried out by chopping off the plants with a native hoe.

When required for silage, planting should take place later, and the crop should be cut when the pods are 1 to $1\frac{1}{2}$ inches long.

A mixture of 2 parts of maize or wintersome to one of velvet beans makes excellent silage.



Fig. 1.

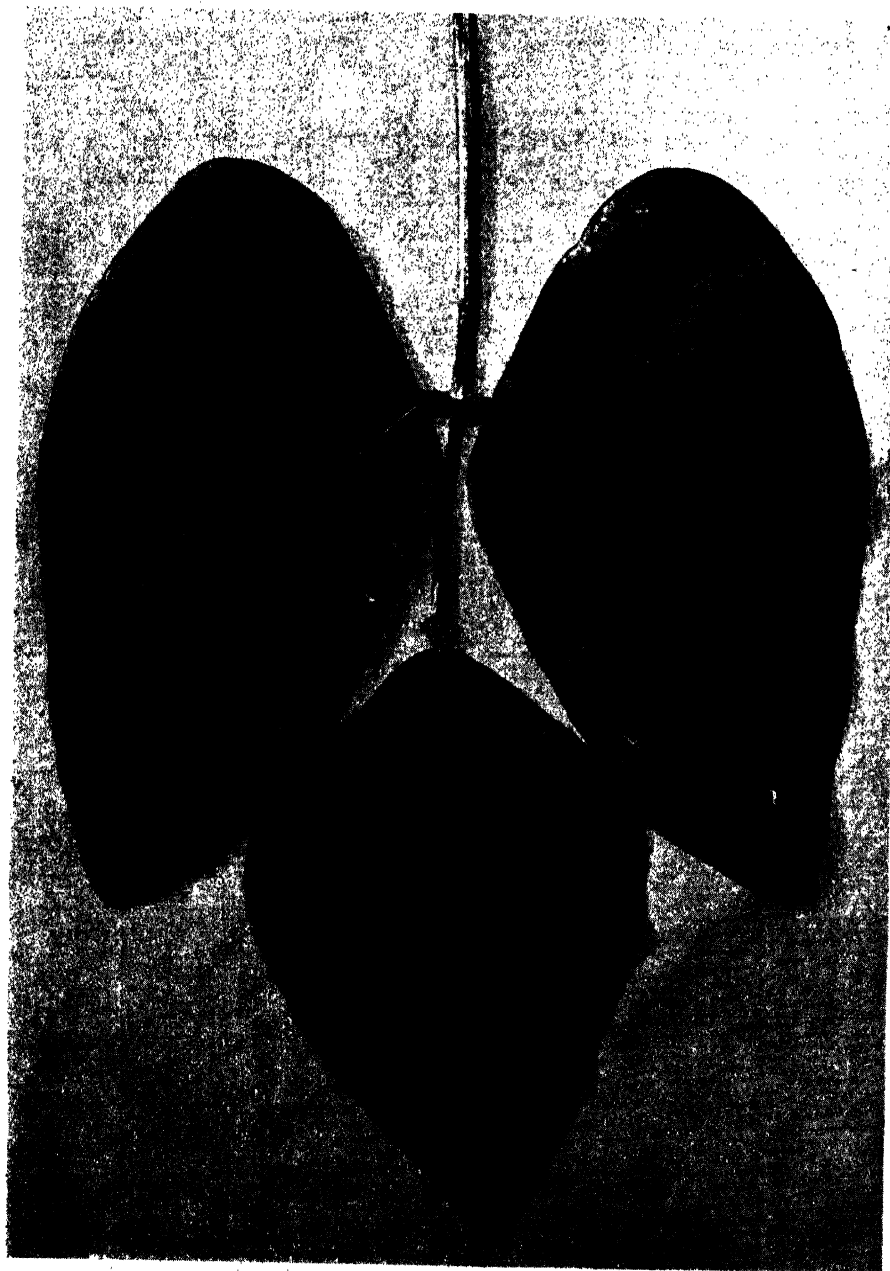


Fig. 2.



Fig. 3.



Fig. 4.



Fig 5.

UTILIZATION OF THE PROTEIN OF SOMERSET BEANS.

The popularity of this crop in Southern Rhodesia and in the Northern Transvaal is due mainly to its ability to thrive under great variation in climatic conditions, also the crop does well on comparatively poor soils. However adverse the climatic conditions may be it seldom fails to yield a crop.

This crop is relatively immune to fungoid disease, is attacked by few insects and is nematode resistant.

EXPERIMENTAL.

The biological value of Somerset bean proteins was determined alone and supplemented by cystine at an 8 per cent. level on rats. These rats were selected according to the usual procedure for the determination of the biological values. They were subjected to a nitrogen free period for the estimation of the body's contribution of nitrogen in the faeces and urine and thereafter put on the protein rations for a preliminary period followed by the usual collection period of 8 days. The composition of the rations is given in Table 1.

Young Merino wethers accustomed to the metabolism crates were utilized to determine the biological value of the Somerset beans. Two periods, one in which Somerset beans alone were fed and the other in which it was supplemented by maize at the same level of nitrogen intake, were run on these immature sheep. A third period in which grazing cut at Ermelo during April was supplemented by Somerset beans, was conducted on mature sheep.

EXPERIMENTAL RESULTS.

In Table 2 are given the detailed results relevant to the calculation of the biological value of Somerset beans on rats. It is at once evident from this table that a large proportion of the nitrogen contained in the above bean is excreted as undigested waste in the faeces. However, the average apparent digestibility of 57 is not a true index of the digestibility of Somerset bean nitrogen since the nitrogen derived from the body and excreted in the faeces is included in the calculation. If the metabolic fecal nitrogen is deducted, then the true digestibility as shown in the table is enhanced and becomes 76. The utilization of the absorbed nitrogen as represented by an average biological value of 37 is indeed low, and indicates that the quality of the protein of this bean is exceptionally poor for maintenance and growth of rats. It is thus evident that certain of the essential amino acids are definitely missing from the amino acid complex constituting the protein molecule of this bean.

Working on this hypothesis, it was decided on the ground of our previous experience with plant proteins to supplement the protein of Somerset beans with 0.2 per cent. of cystine. The results obtained with this supplementation are reproduced in Table 3. From this data it appears as if the apparent digestibility is lowered by the inclusion of this minute amount of cystine. That such should be the case is hardly conceivable, unless the effect of the cystine ingestion

is to stimulate the metabolic fecal nitrogen enhancing the total fecal nitrogen excretion. However, of more importance is the fact that the inclusion of cystine makes the absorbed nitrogen better utilizable by 17 per cent. Somerset beans alone as shown in Table 2 gives a biological value of 37 whereas after supplementation with cystine the biological value is increased to 54. This data definitely confirms an existing deficiency of the indispensable amino acid cystine in the protein of this bean.

In Table 4 are reproduced in tabular form the results in connection with the sheep metabolism experiments. In the first series the biological value of Somerset beans was determined at an approximate level of 7 per cent. protein. The apparent digestibility of 48 as obtained per sheep agrees fairly well with that obtained for rats when cystine supplementation was executed. The true digestibility of 87 is, however, slightly better than 73 obtained for rats. Without cystine supplementation the apparent digestibility with rats is approximately 10 per cent. higher, while the difference in true digestibility remains more or less of the same magnitude. The average biological value obtained under these conditions is 52. This value is decidedly very low for growing sheep at this level of protein feeding. Judging from this result it would appear as if this particular protein is also deficient in some or other indispensable amino acid for the growth requirements of sheep. Thus far it has been assumed on purely theoretical grounds (Rimington and Bekker) that cystine can be synthesized by sheep. This assumption has no experimental basis and is chiefly based on cystine content of wool in comparison with that of grazing. Smuts and Marais have definitely shown that the biological value of lucerne supplemented by cystine is not enhanced above that of lucerne. However, the condition may be quite different in respect to the growing sheep, which may, like rats, require additional cystine above that supplied by lucerne for tissue synthesis.

From the second series of metabolism tests in which half of the Somerset bean protein was displaced by that of maize protein, it would appear as if supplementation has actually taken place. If, however, the biological value of maize at this level of intake is the same as that for rats, namely 67, then one would expect a biological value for the mixed proteins of 60. This value is only 2 per cent. lower than the determined value of 62, and cannot therefore be considered statistically significant. Superficially it would appear as if maize which is known to supplement cystine deficient protein (Smuts and Marais) does not exert this effect with Somerset beans, which may lead one to suspect that either the cystine requirements of sheep are very low and that it is not the limiting amino acid for sheep in Somerset beans, or that sheep can actually synthesize this amino acid. However, it is hoped these points will be settled in the following publication.

In the last series of results, 320 grams of April grazing was supplemented by 100 grams of Somerset beans. Both the apparent digestibility and true digestibility are increased under these conditions. The biological value of 59 is fairly good at this level of protein intake for growing sheep.

UTILIZATION OF THE PROTEIN OF SOMERSET BEANS.

If the Smuts and Marais formula for the estimation of the protein requirements of sheep, namely $P = .74 W^{.784}$ is utilized, it is found that a 100 lb. sheep requires 13.0 grams utilizable protein for maintenance. To satisfy this need by the feeding of Somerset beans it would require 194 grams or 7 oz. of the latter beans. On the other hand, if the general formula of Smuts, namely $P = .88 W^{.784}$ applicable to all species be applied to determine the maintenance requirement of steers, it is found that a 1,000 lb. steer would require 82 grams utilizable protein. In order to satisfy this need through the feeding of Somerset beans, 1,254 grams or approximately 2.7 lb. are to be fed. From the data on the grazing supplemented by Somerset beans it is evident that considerably less is necessary to satisfy the maintenance protein needs of both sheep and cattle.

It must be understood that the requirements as calculated above is only in respect to the protein requirements of the respective species. There is little doubt that the energy contained in the above quantities will considerably augment the depleted energy in the grazing and may even help to satisfy the needs of this element in a substantial way, and may, together with the protein, be the cause of the excellent practical results obtained on it.

CONCLUSION.

By means of carefully controlled metabolism experiments it was shown that the biological value for Somerset beans with rats is 37, and that this value is significantly enhanced by the inclusion of 0.2 per cent. cystine.

The same product when tested out with sheep gave a biological value of 52, and when supplemented in equal proportions, with maize, a value of 62. When April grazing is supplemented by Somerset beans the average biological value obtained is 59.

TABLE 1.
Composition of Rations.

	A.	B.	C.?
Somerset beans.....	30.1	—	30.1
Butterfat.....	8.0	8.0	8.0
Cystine.....	—	—	0.2
Codliver oil.....	2.0	2.0	2.0
Harris yeast.....	2.0	2.0	2.0
Sucrose.....	10.0	10.0	10.0
Salt mixture (Hubbel).....	2.0	2.0	2.0
NaCl.....	1.0	1.0	1.0
Starch dextrinized.....	44.9	69.2	69.2
Whole egg (ether extracted).....	—	3.8	—
Agar.....	—	2.0	—
	100.0	100.0	—
Percentage N.....	1.56	0.64	1.50

TABLE 2.
Biological Value of Somerset Bean Ration.
Nitrogen Metabolism Data and the Calculation of the Biological Value.
N-low Period.

Rat No.	Sex.	Initial Wgt.	Final Wgt.	Aver. age Wgt.	Daily Food In-take.	Daily N In-take.	Metabolic N.			Absorbed N in Nitrogen.	Daily Urinary N.	Endogenous N.		Food N in Urine.	Retained Nitrogen.	Biological Value.	True Digestibility.	Apparent Digestibility.
							Per Gram Food.	Per Day.	Food N in Faeces.			Per 100 Gram Wgt.	Per Day.					
1	—	96	97	97	5.0	—	2.92	—	—	Mgm.	Mgm.	Mgm.	—	—	—	—	—	—
	—	98	100	99	6.8	—	3.24	—	—	—	17.2	17.4	—	—	—	—	—	—
	—	95	97	96	8.0	—	2.45	—	—	—	23.2	24.2	—	—	—	—	—	—
	—	90	87	89	4.7	—	3.49	—	—	—	17.2	19.3	—	—	—	—	—	—
4	—	97	97	97	5.0	—	3.20	—	—	—	13.2	13.6	—	—	—	—	—	—
5	—	109	110	110	8.5	—	2.40	—	—	—	21.2	19.3	—	—	—	—	—	—
6	—																	

Somerset Bean Ration 1.56 per cent. N.																		
1	100	90	95	8.0	124.8	53.6	2.92	23.4	30.2	94.6	69.6	11.5	10.9	58.7	35.9	38	76	57
2	101	91	96	7.4	115.4	52.0	3.24	24.0	28.0	87.4	73.6	17.4	16.7	56.9	30.5	35	76	55
3	104	92	98	8.1	126.4	45.6	2.45	19.8	25.8	100.6	91.2	24.2	23.7	67.5	33.1	33	80	64
4	95	89	92	8.1	126.4	60.0	3.49	28.3	31.7	94.7	74.4	19.3	17.8	56.6	38.1	40	75	53
5	102	90	96	8.7	135.7	64.0	3.20	27.8	36.2	99.5	76.8	13.6	13.1	63.7	35.8	36	73	53
6	107	101	104	8.4	131.0	50.4	2.40	20.2	30.2	100.8	81.6	19.3	20.1	61.5	39.3	39	77	62
																37	76	57

TABLE 3.
Biological Value of Somerset Bean + 0.2 per cent. Cystine.
Nitrogen Metabolism Data and the Calculation of the Biological Value.
N-low Period.

Rat No.	Sex.	Initial Wgt.	Average Wgt.	Daily Food In-take.	Daily N In-take.	Daily Faecal In-take.	Metabolic N.			Food N in Faeces	Absorbent Nitrogen.	Daily Urinary N.	Endogenous N.		Food N in Urine.	Retained Nitrogen.	Biological Value.	True Digestibility.	Apparent Digestibility.
							Per Gram Food.	Per Day.	Per 100 Gram Wgt.				Per 100 Gram Wgt.	Per Day.					
1	—	121	117	119	8.1	32.0	3.95	—	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	Mgm.	—	—	—	—	—
2	—	125	125	125	9.8	38.4	3.92	—	—	—	24.6	19.7	—	—	—	—	—	—	—
3	—	131	127	129	7.9	34.0	4.30	—	—	—	27.9	21.6	—	—	—	—	—	—	—
4	—	124	120	122	7.6	29.6	3.89	—	—	—	23.6	19.3	—	—	—	—	—	—	—
5	—	124	126	125	11.8	45.6	3.86	—	—	—	26.8	21.4	—	—	—	—	—	—	—
6	—	130	126	128	10.3	42.0	4.08	—	—	—	26.0	20.3	—	—	—	—	—	—	—
<i>Somerset Beans + 0.2 per cent. Cystine per cent N 1.53.</i>																			
1	—	110	102	106	8.8	134.6	64.4	39.5	34.8	29.6	105.0	63.4	16.6	45.8	59.2	56	78	52	47
2	—	112	105	109	9.4	143.8	75.2	3.92	36.8	38.4	105.4	72.4	19.7	50.9	54.5	52	73	48	48
4	—	108	98	103	7.1	108.6	59.2	3.89	27.6	31.6	77.0	64.2	19.3	44.3	32.7	42	71	45	45
4	—	108	98	103	7.1	108.6	59.2	3.89	27.6	31.6	77.0	64.2	19.3	44.3	32.7	42	71	45	45
5	—	110	104	107	8.9	136.2	66.4	3.86	34.4	32.0	104.2	61.5	21.4	38.6	65.6	63	77	51	51
6	—	111	102	107	9.7	148.4	95.6	4.08	39.6	56.0	92.4	61.3	20.3	39.6	52.8	57	62	36	36

TABLE 4.
Data on the Nitrogen Utilization of Somerset Beans with Sheep.

Animal No.	Average Lot.	Food Consumption.			Dry Matter Intake.	Nitrogen Intake.	N in Faeces.	Metabolic Faecal N.†	Absorbed N.	N in Urine.	Endogenous N.*	Food N Retained.	Biological Value.	N Balance.	Apparent Digestibility.	True Digestibility.
		Wheat Straw.	Somer-set Beans.	Starch.												
<i>Maize.</i>																
	Kgms.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gram.	Per cent.	Per cent.
1	27	300	100	100	460	5.73	2.80	2.30	5.23	3.31	0.83	2.75	53	-0.39	52	91
2	27	300	100	100	460	5.73	3.12	2.30	4.91	3.24	0.83	2.50	51	-0.63	46	86
3	26	300	100	100	460	5.73	3.21	2.30	4.62	3.08	0.81	2.35	51	-0.56	44	81
4	26	300	63	13	346	4.15	2.14	1.73	3.74	2.66	0.81	1.90	53	-0.65	48	90
5	26	300	100	63	418	5.73	2.95	2.09	4.87	3.25	0.81	2.43	50	-0.47	49	85
												Average			48	87
<i>Maize.</i>																
	Kgms.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gram.	Per cent.	Per cent.
1	27	300	50	125	437	5.65	2.51	2.19	5.33	3.08	0.83	3.08	59	+0.06	56	94
2	27	300	50	125	437	5.65	2.63	2.19	5.21	2.74	0.83	3.30	63	+0.28	53	92
3	26	300	50	125	437	5.65	2.62	2.19	5.22	2.74	0.81	3.29	63	+0.29	53	92
4	26	300	50	125	437	5.65	2.48	2.19	5.36	2.77	0.81	3.40	63	+0.40	56	95
5	26	300	50	125	437	5.65	3.17	2.19	4.67	2.66	0.81	2.82	60	-0.18	44	83
												Average			52	91
<i>Mature sheep April grazing + Sussex Beans.</i>																
	Kgms.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gram.	Per cent.	Per cent.
7	43	320	—	100	387	7.36	2.52	1.94	6.78	4.16	1.17	3.79	56	+0.68	66	92
8	40	320	—	100	387	7.36	2.81	1.94	6.49	3.75	1.10	3.84	59	+0.80	62	88
9	40	320	—	100	387	7.36	3.09	1.94	6.21	3.75	1.10	3.56	57	+0.52	58	84
10	40	320	—	100	387	7.36	2.45	1.94	6.85	3.46	1.10	4.49	65	+1.45	67	93
												Average			63	89

* The endogenous N was calculated from P. = .74 W.⁷³⁴

† The metabolic faecal N was calculated from the average figure of .005 grams N per gram dry matter consumed.



The Amino Acid Deficiencies of Certain Plant Proteins and the Supplementary Effect between Plant Proteins as measured by means of their Biological Values.

By J. S. C. MARAIS and D. B. SMUTS, Section of Nutrition,
Onderstepoort.

IN previous work by the authors (1938-9) the amino acid deficiencies of different plant proteins were established by means of the paired feeding method. As was pointed out then, the paired feeding method, which measures the response caused, by the inclusion of certain amino acids in terms of growth, does not supply any information regarding the metabolic effect of these minute amounts of amino acids on the utilizability of the nitrogen complex contained in the plant proteins. In order to obtain this desired information, as well as additional proof of the amino acids limiting the nutritive value of the proteins, the biological values of the supplemented plant proteins were determined. From the combined data it is not only possible to obtain a detailed picture of the changes in nitrogen metabolism, which are caused by the absence or presence of certain indispensable amino acids, but also to apply this information in the economical nutrition of farm animals. Thus it may be known that lucerne is deficient in cystine, but unless the nitrogen conservation through the addition of cystine, and the extent to which other feeds in practice can supplement this cystine deficiency, are known, the results remain of purely academic value. For these reasons a separate study on the biological utilization of the supplemented plant proteins was undertaken which, in conjunction with the results of the paired feeding tests, will afford a scientific basis for the future selection and balancing of protein feeds in rations for livestock.

In this study the supplementary effect of methionine on lucerne, lysine on whole oats seed, cystine and methionine on peanutmeal, cystine on linseedmeal and the supplementary relationship between whole yellow maize and lucerne and soyabeans have been investigated.

That methionine has a supplementary effect on the proteins of lucerne has already been shown by the authors (1940) by means of the paired feeding method. Similarly McCollum and Simmonds (1916) and Mitchell and Smuts (1932) obtained evidence of a lysine deficiency of oats. The supplementary relationship between gelatin

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and oats has been explained by McCollum and co-workers (1917) as due to the lysine content of the gelatin. Mitchell (1924), however, could not establish any supplementary relationship between oats and gelatin mixed in the proportions of 3:1 by means of their respective biological values.

A methionine deficiency has been ascribed by Beach and White (1937) and Baernstein (1938) to arachin, one of the protein components of the peanut. In paired feeding experiments by the authors (1938-39) no cystine or methionine deficiencies could be established for the proteins of peanutmeal. Indications of slight improvements when supplementing with the two amino acids were, however, observed, but were so small as to be insignificant. In the same year evidence was obtained of the cystine deficiencies of linseed and soya-bean meals. Notwithstanding the amino acid deficiencies of lucerne and yellow maize Kellermann (1935) obtained normal growth on rats with a mixture of yellow maize and lucerne proteins. Since this protein mixture was not improved by the addition of 0.15 per cent. l-cystine it must be concluded that the proteins supplemented each other in respect to cystine.



Fig. 1.

EXPERIMENTAL.

In determining the supplementary effect of the amino acids on the different proteins the method described by Mitchell (1924) was adopted. Young male rats were used throughout, only one biological value was determined on a series of six rats. Specially constructed earthenware metabolism cages, as illustrated (Fig. 1) were used. The rats stand on a horizontal wire screen (Fig. 2) with a $\frac{3}{8}$ inch mesh which allows the faeces to drop through on to a second wire gauze (Fig. 3) on which it is then collected.

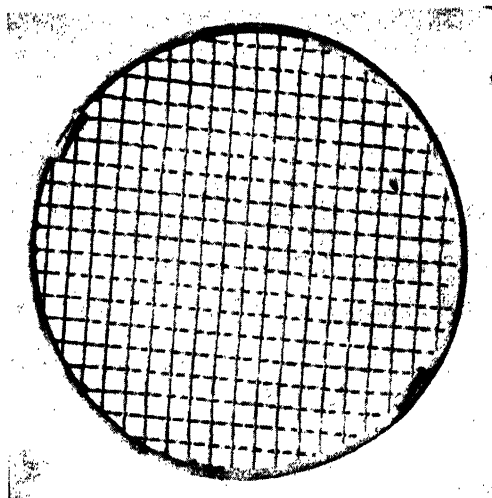


Fig. 2.

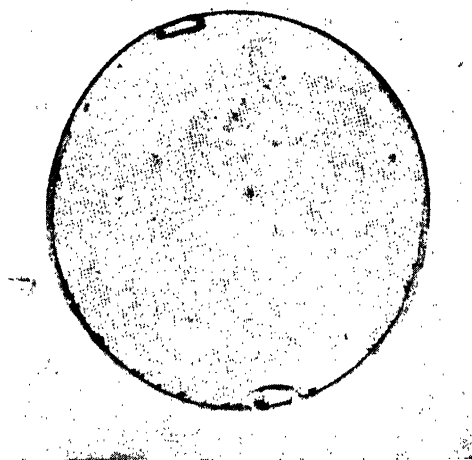


Fig. 3.

AMINO ACID DEFICIENCIES OF PLANT PROTEINS.

The urine and faeces were collected daily. The daily faeces collections, after careful removal of adhering hair, were digested according to the usual Kjeldahl method. The week's digests were made up to volume and analysed for nitrogen. For the urine collections the metabolism cages were washed out daily with 0.5 per cent. tartaric acid solution. The daily urine collections were kept in dilute H_2SO_4 and at the end of the collection period made up to volume and a suitable aliquot digested for the nitrogen determination. To distinguish between faeces of the preliminary and collection periods Fe_2O_3 was used as a marker. The collection periods were of seven days' duration. The nitrogen low period was conducted either prior to or after the protein periods. Six to seven days were allowed on the nitrogen low ration to establish constant nitrogen excretion. For the protein periods at least 10 days were allowed.

To prevent food wastages a special food basin (Fig. 4) was used.

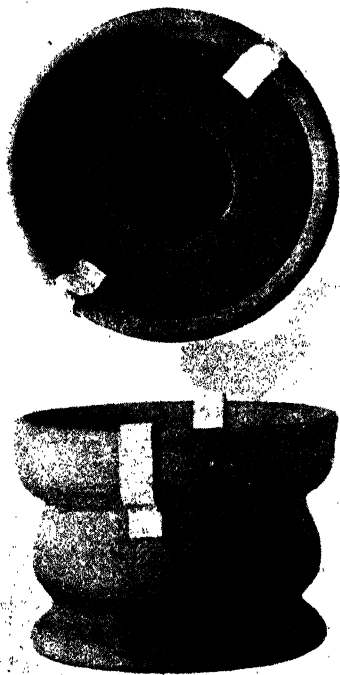


Fig. 4.

The rations were made up so as to contain approximately 8 per cent. crude protein. The rations were stored in an ice chest to prevent deterioration. The composition of the rations is given in Table 1.

TABLE 1.
Percentage Composition of the Rations.

	N—Low.	N—Low.	Lucerne + Methio- nine.	Oats + Lysine.	Peanut + Cystine.	Peanut + Methio- nine.	Linseed + Cystine.	Yellow Maize + Lucerne.	Yellow Maize + Soybeans.
Lucerne meal.....	—	—	39.3	—	—	—	—	20.5	—
Whole oats seed.....	—	—	—	68.2	—	—	—	—	—
Peanutmeal.....	—	—	—	—	15.3	14.2	—	—	—
Linseedmeal.....	—	—	—	—	—	—	22.5	—	—
Whole yellow maize meal.....	—	—	—	—	—	—	—	42.1	42.1
Soyabean meal.....	—	—	—	—	—	—	—	—	10.2
l-cystine.....	—	—	—	—	0.2	0.2	0.2	—	—
dl-methionine.....	—	—	0.2	—	—	—	—	—	—
dl-lysine-di-hydrochloride.....	—	—	—	0.2	—	—	—	—	—
Whole egg white (1).....	3.8	3.8	—	—	—	—	—	—	—
Whole egg (2).....	—	—	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Sucrose.....	10.0	10.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Butterfat (3).....	8.0	8.0	—	—	—	—	—	—	—
Yeast Extract (4).....	10.0	10.0	—	—	10.0	—	—	—	—
Harris Yeast (5).....	—	—	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Cod Liver Oil.....	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Salt mixture (Osborne & Mendel) (6).....	4.5	4.5	—	—	4.5	—	—	—	—
Salt mixture (Hubbel, etc.) (7).....	—	—	2.0	2.0	—	2.0	2.0	2.0	2.0
Starch (dextrinized).....	5.87	69.2	35.2	6.6	49.0	60.6	52.3	12.4	22.7
NaCl.....	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Agar.....	2.0	2.0	—	—	—	—	—	—	—
TOTAL.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PERCENTAGE N.....	0.65	0.63	1.45	1.45	1.34	1.44	1.47	1.58	1.56

(1) The whole egg white has been dried on a waterbath and extracted with ether.

(2) The whole egg has been dried on a waterbath and extracted with ether.

(3) The butterfat has been filtered through a coarse filter paper to remove casein.

(4) A yeast extract prepared according to the method of Iter, S., Orent, E. R. and McCollum, E. V. (1935). *J. Biol. Chem.* Vol. 108, pp. 571–577.

(5) Harris Yeast a preparation of "The Harris Laboratories, Tuckahoe, New York.

(6) A modified Osborne and Mendel Salt mixture described by Hawk, P. B. and Osler, B. L. (1931). *Science*, Vol. 74, pp. 369.

(7) A new salt mixture described by Hubbel, R., Mendel, J. B. and Wakeman, A. J. (1937), *J. Nutr.* Vol. 14, pp. 273–283.

RESULTS.

From the experimental data given in Table 2, it will be seen that the biological values for lucerne + 0.2 per cent. dl-methionine, whole oats seed + 0.2 per cent. d-lysine-di-hydrochloride, peanutmeal + 0.2 per cent. l-cystine, peanutmeal + 0.2 per cent. dl-methionine, linseedmeal + 0.2 per cent. l-cystine, yellow maize + lucerne and yellow maize + soyabeans are 90 ± 0.68 , 86 ± 1.00 , 66 ± 1.81 , 78 ± 1.53 , 86 ± 0.68 , 80 ± 0.61 and 75 ± 2.77 respectively. According to Smuts and Malan (1938) the biological values for lucernemeal, peanutmeal and linseedmeal are 60 ± 1.49 , 72 ± 1.61 and 78 ± 1.92 respectively, while the biological values of whole oats seed, whole yellow maize and soyabeans are according to Smuts and Marais (1938-40) 83 ± 2.04 , 67 ± 0.98 and 55 ± 1.72 respectively. It is, therefore, clear that the supplementation of lucerne with 0.2 per cent. dl-methionine improved the nitrogen utilization of the lucerne proteins by 30 ± 1.64 per cent. This improvement is very nearly the same as that obtained previously (1938) for the supplementation with 0.2 per cent. l-cystine, namely 28 ± 2.46 per cent. This enhancement in the biological value of the supplemented protein verifies the previous results (1939) obtained by means of the paired feeding method.

The supplementation of the proteins of oats seed with 0.2 per cent. d-lysine-di-hydrochloride gave only a slight increase of 3 ± 2.27 , which signifies no significant improvement and the lysine deficiency of oats must be regarded as only of very little importance. The biological value of peanutmeal supplemented with cystine definitely proves that the protein of peanutmeal is not deficient in cystine, since supplementation even lowered the biological value. The result of the methionine supplementation on the other hand indicates that the proteins of peanutmeal may be deficient in methionine as a 6 ± 2.22 per cent. increase in the nitrogen utilization was obtained. This would seem to be in agreement with the findings of Beach and White (1937) and Baernstein (1938) on the methionine deficiency of arachin.

The increased nitrogen utilization of 8 ± 2.04 per cent., caused by the supplementation of linseedmeal with 0.2 per cent. l-cystine agrees very well with the results of Smuts and Marais (1938) by means of the paired feeding method and definitely establish the cystine deficiency of linseedmeal.

If no supplementary relationship existed between the proteins of yellow maize and lucerne and yellow maize and soyabeans, the mean biological values of the protein mixtures would have been 64 ± 1.26 and 61 ± 1.40 respectively. It will be seen, however, that the biological values are actually 80 ± 0.61 and 75 ± 2.77 for the protein mixtures of yellow maize + lucerne and yellow maize + soyabeans. The differences obtained namely 16 ± 1.40 and 14 ± 3.10 definitely prove that there exists a supplementary relationship between these proteins. The supplementations are perfectly in harmony with the respective amino acid deficiencies of the proteins. The proteins of yellow maize are deficient in lysine and tryptophane whereas the proteins of lucerne and soyabeans are markedly deficient

in cystine. It is, therefore, clear that the maize proteins can supplement the cystine deficiency of lucerne and soyabeans, while the proteins of lucerne and soyabeans can again supplement the lysine-tryptophane deficiency of the maize proteins.

It is evident that the present data on the amino acid deficiencies of the different proteins may serve as a basis for predicting any possible supplementary relationship between mixed proteins.

SUMMARY AND CONCLUSIONS.

The supplementary effect of methionine on lucerne, lysine on oats seed, cystine and methionine on peanutmeal, cystine on linseed-meal as well as the supplementary relationship between yellow maize and lucerne and of yellow maize and soyabeans have been determined by means of their biological values. From the results obtained it is concluded:—

1. That 0.2 per cent. dl-methionine increased the nitrogen utilization of the lucerne proteins by 30 ± 1.64 per cent.
2. Cystine has no supplementary effect on peanutmeal, while methionine improves the protein to a slight extent.
3. Cystine supplementation increases the nitrogen utilization of linseedmeal by 8 ± 2.04 per cent.
4. Lysine supplementation has no significant effect on the proteins of whole oats seed.
5. The proteins of whole yellow maize and lucerne and of whole maize and soyabeans supplement each other in a marked and significant manner.

REFERENCES.

- BAERNSTEIN, H. D. (1938). The nutritive value of various protein fractions of the peanut. *J. Biol. Chem.*, Vol. 122, p. 781-789.
- BEACH, F. F., AND WHITE, A. (1937). Methionine as the limiting nutritive factor of arachin. *J. Biol. Chem.*, Vol. 119, VIII-IX proc.
- KELLERMANN, J. H. (1935). Further observations on the cystine deficiency of lucerne proteins and the effect of heat and incubation upon their growth promoting value. *Onderstepoort J. Vet. Sci. and Animal Indust.*, Vol. 4, p. 437-452.
- MARAIS, J. S. C., AND SMUTS, D. B. (1940). Further studies of the amino acid deficiencies of plant proteins. *Onderstepoort J. Vet. Sci. and Animal Indust.*, Vol. 14, Nos. 1 and 2, pp. 387-402.
- MCCOLLUM, E. V., AND SIMMONDS, P. (1916). Lysine as a limiting amino acid in oats. *J. Biol. Chem.*, Vol. 28, p. 483-490.
- MCCOLLUM, E. V., SIMMONDS, N., AND PITZ, W. (1917). The nature of the dietary deficiencies of the oat kernel. *J. Biol. Chem.*, Vol. 29, p. 341.
- MITCHELL, H. H. (1934). A method of determining the biological value of protein. *J. Biol. Chem.*, Vol. 58, p. 873-903.
- MITCHELL, H. H. (1924). The supplementary relations among protein. *J. Biol. Chem.*, Vol. 58, p. 923.

AMINO ACID DEFICIENCIES OF PLANT PROTEINS.

- MITCHELL, H. H., AND SMUTS, D. B. (1932). The amino acid deficiencies of beef, wheat, corn, oats and soyabeans for growth in the white rat. *J. Biol. Chem.*, Vol. 95, p. 263-281.
- SMUTS, D. B., AND MALAN, A. I. (1938). Plant Proteins II. The biological values of lucernemeal, sesamemeal, peanutmeal, coprameal, cottonseedmeal and oatmeal. *Onderstepoort J. Vet. Sci. and Animal Indust.*, Vol. 10, p. 207-219.
- SMUTS, D. B., AND MARAIS, J. S. C. (1938). Plant Proteins III. The supplementary effect amongst certain plant proteins. *Onderstepoort J. Vet. Sci. and Animal Indust.*, Vol. 11, p. 151-159.
- SMUTS, D. B., AND MARAIS, J. S. C. (1938). Plant Proteins IV. The biological values of soyabeans, linseedmeal and soyabeans supplemented by cystine. *Onderstepoort J. Vet. Sci. and Animal Indust.*, Vol. 11, p. 391-397.
- SMUTS, D. B., AND MARAIS, J. S. C. (1938). Plant Proteins VI. The amino acid deficiencies in certain plant proteins. *Onderstepoort J. Vet. Sci. and Animal Indust.*, Vol. 11, p. 407-416.
- SMUTS, D. B., AND MARAIS, J. S. C. (1939). The effect of supplementing lucerne with cystine and methionine on the growth of rats. *Onderstepoort J. Vet. Sci. and Animal Indust.*, Vol. 12, p. 369-375.
- SMUTS, D. B., AND MARAIS, J. S. C. (1940). The biological values of the proteins of oats, barley, wheatbran and pollard. *Onderstepoort J. Vet. Sci. and Animal Indust.* In press.
- SMUTS, D. B., AND MARAIS, J. S. C. (1940). The biological values of maize and maize supplemented with lysine and tryptophane. *Onderstepoort J. Vet. Sci. and Animal Indust.* In press.

Rat Number.	N.		Food N in Urine.	N Retained.	N Balance.	Biological Value.
	Initial Weight	Day.				
	Gm.	gm.	Mgm.	Mgm.	Mgm.	
1.....	115	—	—	—	—	—
2.....	95	—	—	—	—	—
3.....	87	—	—	—	—	—
4.....	116	—	—	—	—	—
5.....	90	—	—	—	—	—
6.....	92	—	—	—	—	—
1.....	153	27.7	13.1	136.5	+65.0	91
2.....	134	26.7	13.8	133.8	+65.6	91
3.....	125	20.9	16.1	136.4	+84.7	91
4.....	149	25.9	21.1	141.8	+69.0	87
5.....	132	28.4	14.3	142.2	+72.5	91
6.....	125	23.0	14.6	150.7	+72.0	91
						90
1.....	100	—	—	—	—	—
2.....	128	—	—	—	—	—
3.....	140	—	—	—	—	—
4.....	127	—	—	—	—	—
5.....	135	—	—	—	—	—
6.....	140	—	—	—	—	—
1.....	100	24.4	28.0	127.9	+69.1	82
2.....	115	27.3	28.3	161.4	+87.6	85
3.....	132	27.8	28.2	184.1	+100.9	87
4.....	112	26.6	25.4	192.8	+120.8	88
5.....	125	28.0	22.0	161.3	+86.7	88
6.....	127	23.8	23.8	182.6	+106.2	88
						86

Rat Number.	Initial Weight.	Final Weight	N Retained.	N Balance.	Apparent Digestibility.	True Digestibility.	Biological Value.
	Gm.	Gm.	Mgm.	Mgm.			
1	88	88	—	—	—	—	—
2	87	83	—	—	—	—	—
3	97	92	—	—	—	—	—
4	98	92	—	—	—	—	—
5	95	91	—	—	—	—	—
6	90	92	—	—	—	—	—

1	103	111	92.5	+ 52.2	73	91	78
2	111	124	132.6	+ 73.5	73	95	79
3	116	130	134.7	+ 75.7	72	94	82
4	112	124	132.8	+ 69.1	69	93	81
5	111	136	143.8	+ 84.8	73	96	81
6	123	138	145.9	+ 79.4	70	94	80
					72	94	80

1	114	111	—	—	—	—	—
2	120	120	—	—	—	—	—
3	113	114	—	—	—	—	—
4	116	116	—	—	—	—	—
5	110	108	—	—	—	—	—
6	123	123	—	—	—	—	—

1	120	111	62.5	+ 21.8	73	97	75
2	123	121	69.4	+ 29.4	71	94	77
3	112	111	92.2	+ 33.0	66	90	66
4	113	111	72.5	+ 21.0	66	95	85
5	114	111	86.0	+ 42.8	70	94	78
6	118	121	81.1	+ 25.9	61	85	69
					68	93	75

Section III.

Pharmacology and Toxicology.

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Senecio Alkaloids—Part III.

Chemical Investigations upon the Senecio Species Responsible for "Bread-poisoning." The Isolation of Senecionine from *Senecio ilicifolius* Thunb. and a New Alkaloid "Rosmarinine" from *Senecio rosmarinifolius* Linn.

By H. L. DE WAAL, Section of Pharmacology and Toxicology,
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IN the South-Western districts of the Cape Province, especially in the Knysna, George, Riversdale and Mossel Bay districts, certain species of the Senecio plants (Fam. Compositae) grow abundantly. The following are found as "weeds" on cultivated wheat-lands: *Senecio ilicifolius* (abundant), *S. burchellii* (abundant), *Senecio rosmarinifolius* (fairly common) as well as certain other species which do not occur so abundantly.

It is very well known that *S. ilicifolius* is the cause of "bread-poisoning" in human beings, and the other two species are also suspected poisonous plants. Chemical investigations already carried out by certain workers on various species of Senecio led to the isolation of the toxic principles namely alkaloids. [See Steyn (1934); de Waal (1939, 1940); Barger and Blackie (1936, 1937); Manske (1931, 1936, 1939); Orechhoff *et al* (1935)]. The toxic alkaloids present in these plants cause the typical chronic cases of liver-cirrhosis in human beings as well as in animals, e.g., horses ("Dunsiekte", "Horse-Staggers", "Walking" disease, "Poisonous ragwort", "Winton" disease, etc.), sheep and cattle.

In the Cape South-Western districts where animal husbandry plays a minor rôle in farming, animal losses due to Senecio poisoning, are not so frequent. Moreover, there is sufficient other green grazing during spring and the early summer months when the young Senecio plants sprout. As these Senecio species grow freely and abundantly on cultivated grain lands, contamination of the threshed wheat easily takes place with the seeds and pieces of the stem of these plants. The

plants are harvested with the wheat and deficient winnowing and sieving appliances of the threshing machines readily pass the seed and pieces of the stem into the wheat bag, mainly into the third-class wheat. Steyn (1934) recorded the results of his investigations and described how specimens of wheat used for human consumption contained sticks of these plants up to two inches long. Even with the very best winnowing appliances seeds and sticks of at least the same size as the wheat grains will pass through the wheat. It may be pointed out here that chemical investigation proved that the toxic principle was present in the seeds as well as in the leaves and stems of *S. ilicifolius*.

The abundance of these plants on many of these wheat-lands, ready for harvesting, must be very alarming to the consumers of bread manufactured from such wheat (especially the third-class wheat) and to those families where the main diet consists of bread.

When the author visited the George district at the end of November, 1938 to collect Senecio plants for chemical investigation he witnessed the abundance of *S. ilicifolius* Thunb. on wheat-lands. Its predominance all along the coastal districts as far east as East London is also very well known. *Senecio rosmarinifolius* Linn. and *S. burchellii* D.C. are also very common in these parts, the former being frequently found here while the latter has a very wide distribution throughout South Africa.

THE TOXICITY OF SENECIO PLANTS.

From information obtained from the Government Extension Officer at George, four cases of "bread-poisoning" in human beings occurred in the Knysna district during 1937. Steyn (1934) recorded a natural case of chronic seneciosis in a horse on a farm where seven cases of "bread-poisoning" had occurred. On investigation, a corner of the land on which the wheat for household purposes was grown was found heavily overgrown with *Senecio burchellii* D.C.

In this article the results of the chemical investigation upon *S. ilicifolius* Thunb. and *S. rosmarinifolius* Linn. for their toxic principles are described. About six miles outside George the author gathered on 30.11.1938 forty bags of *S. ilicifolius* in the post-flowering stage (i.e., the stage in which it is harvested with the wheat) on a small area of less than an acre of cultivated land. The plants were three to five feet high and grew so profusely that the field had the appearance of a cultivated Senecio land.

When Dr. D. G. Steyn and the author investigated the problem of Senecio poisoning in stock, especially prevalent in horses and sheep in the Transkeian and East London areas, in September and again in November, 1939, the same phenomenon was observed with *S. pterophorus* D.C.

This species closely resembles *S. ilicifolius* and belongs to the same Senecio group: Rigid. Both *S. ilicifolius* and *S. pterophorus* spread very easily and rapidly so that their occurrence has become alarmingly abundant. On account of the fact that these Senecio

plants are allowed to grow freely and densely it has become impossible to plough them under completely. In fact when the *Senecio* are in flower in summer such fields have the appearance of huge yellow flowering gardens.

The other species collected for this investigation was *S. rosmarinifolius* Linn. which occasionally appeared in thick patches in valleys or on pasture lands. The author collected ten bags of this plant in the flowering stage in the Mt. Pleasant locality on 1.12.1938, about 25 miles from George. A year later 40 more bags of this plant in the flowering stage were received from the same locality.

The toxic principles of both these *Senecio* species are two stable alkaloids with high melting-points (208° and 232° C.) and are not decomposed when exposed to light, air or moderate heat. They are not decomposed during the baking of bread from flour ground from *Senecio*-contaminated wheat. Both alkaloids are also very sparingly soluble in water. The only remedy must therefore be to eradicate these plants completely in the pre-flowering stage on infested farms. For this purpose the Union Government and every farmer will have to co-operate in perfect harmony to ensure the complete destruction of such poisonous *Senecio* plants.

EXPERIMENTAL PART.

The Isolation of the toxic Alkaloid Senecionine from S. ilicifolius Thunb.

Five kilograms of the dried and ground plant material was extracted with 96 per cent. alcohol in a large extraction apparatus (Soxhlett principle) for two days. The alcohol was distilled off under reduced pressure and the watery residue treated with four litres of 4 per cent. hydrochloric acid and allowed to stand for about 3 days. The clear tawny-coloured supernatant was then decanted or filtered from the heavy tarry deposit and repeatedly shaken with commercial ether until the ether layer was practically colourless (about five shakings). Air was then drawn through the clear brown solution to expel the ether.

The clear acid solution was made alkaline with 5 per cent. ammonium hydrate and then thoroughly shaken with successive quantities of technical chloroform until no more alkaloid was removed. The ammoniacal solution on evaporation left no traces of any alkaloid.

The chloroform solution was washed with water only once and then allowed to evaporate in front of a fan at room temperature. The residue was dissolved in 3 per cent. hydrochloric acid, again shaken with ether, made alkaline with ammonia, shaken with chloroform, the chloroform solution washed and allowed to evaporate. A crystalline residue resulted, which was washed with a little cold acetone, followed by ether, dried and recrystallized from 90 per cent. alcohol.

After three recrystallizations the prismatic colourless crystals (see Fig. 1) melted with decomposition at 232.3° C. (corr.)* The yield was 1 gm. of alkaloid, i.e., 0.02 per cent.

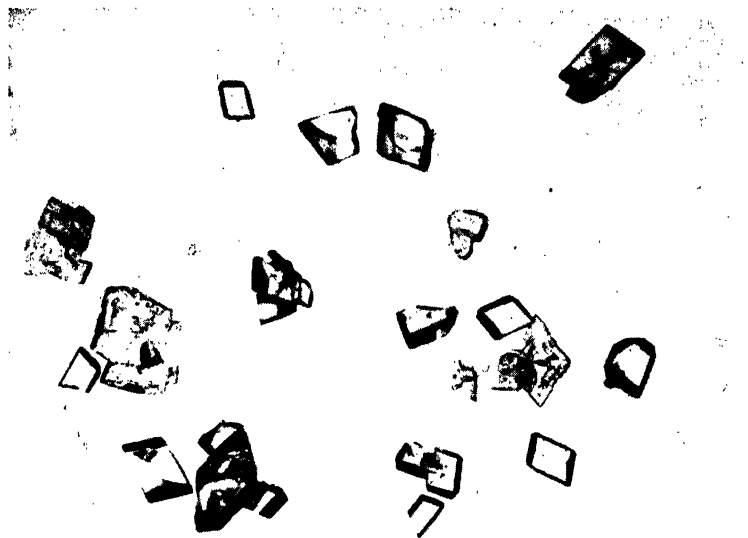


Fig. 1.—Senecionine $\times 24$.

Micro-analysis.[†]

- (i) 3.550 mgm.: 8.444 mgm. CO_2 and 2.414 mgm. H_2O .
4.124 mgm.: 0.201 c.c. N_2 at 621 m.m. and 25° C.
- (ii) 3.395 mgm.: 8.065 mgm. CO_2 and 2.261 mgm. H_2O .
4.062 mgm.: 0.194 c.c. N_2 at 621 m.m. and 25° C.

Found—

- (i) C=64.87 per cent.; H=7.61 per cent.; N=4.61 per cent.
- (ii) C=64.79 per cent.; H=7.45 per cent.; N=4.58 per cent.

Calculated for $\text{C}_{18}\text{H}_{25}\text{O}_5\text{N}$:

C=64.50 per cent.; H=7.51 per cent.; N=4.20 per cent.

Solubility.

The substance dissolved very readily in chloroform and was also soluble in acetone, methyl- and ethyl-alcohol. It was sparingly soluble in cold water, but dissolved in hot water. It was insoluble in ether, petroleum-ether and benzene.

* All melting-points recorded with the Kofler micro-melting point apparatus and are therefore corrected.

[†] All micro-analyses by Dr. O. G. Backeberg, of the University of the Witwatersrand, Johannesburg.

Chemical Properties.

The substance proved to be an alkaloid. It tasted very bitter (typical of the other *Senecio* alkaloids) and decolourized soda-alkaline potassium permanganate solution. It dissolved readily in dilute mineral acid solutions and gave positive reactions with the alkaloidal reagents, viz., Wagner's, Dragendorff's and Mayer's reagents, phosphotungstic and picric acid solutions.

Specific Rotation.

weight = 50.0 mgm.

volume = 8.0 c.c. chloroform.

$$\theta_{\text{D}} = -35^{\circ}.$$

$$[a]_{\text{D}}^{20} = \frac{-35 \times 1000 \times 8}{1 + 50}^{\circ}$$

$$= -56.0^{\circ}.$$

The properties of *Senecionine* (Barger and Blackie, 1936, and Manske, 1936) are identical with those of the isolated substance. The formula of *Senecionine* is $\text{C}_{18}\text{H}_{25}\text{O}_5\text{N}$, its melting-point is 232°C ., its specific rotation is -55.6 (chloroform), its alkaloid reactions, its solubility and other chemical properties are all identical with those of the isolated substance.

Therefore the toxic principle isolated from *S. ilicifolius* Thunb. is the alkaloid *Senecionine*.* This alkaloid is responsible for "bread-poisoning" and was found to be present in the seeds, leaves and stems of the plant.

Isolation of a new Alkaloid "*Rosmarinine*" from *Senecio rosmarinifolius* Linn.

Approximately 7.0 kilograms of dried and ground *S. rosmarinifolius* was introduced into the large extractor and the extraction and working up of the material was carried out exactly similar to that described for *S. ilicifolius* Thunb. (above). As in the case of *S. ilicifolius* no trouble with emulsions was experienced when the ammoniacal liquid was shaken with chloroform. From the chloroform solution, on evaporation, a new alkaloid was isolated for which the name *rosmarinine* is proposed. No other alkaloid was found to be present in the resultant ammoniacal solutions after the treatment with chloroform.

The crystalline residue after the evaporation of the chloroform was washed with cold acetone with the addition of a small volume of ethanol to effect complete solution. The substance rapidly crystallized in a pure state and almost quantitatively. The pure substance crystallized in small, shining, snow-white, squarish flakes with a constant melting-point of 208°C . From 20 per cent. ethanol it crystallizes in pyramidal columns (see Fig. 2). A substantial yield of 0.1 per cent. alkaloid, calculated on the dried and ground plant material, was obtained.

* Since this article had been submitted to the Press two more alkaloids have been isolated from this species, viz., *retvorsine* and a new alkaloid *ptero-phine* ($\text{C}_{18}\text{H}_{25}\text{O}_5\text{N}$) so that *S. ilicifolius* contains three very toxic alkaloids.

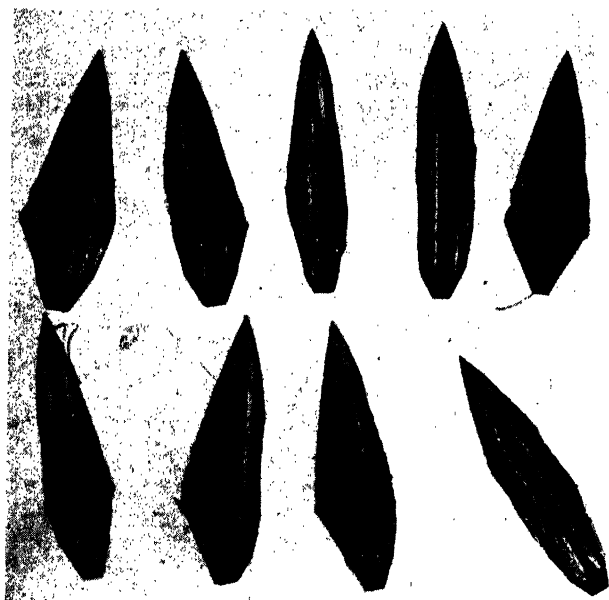


Fig. 2.—Rosmarinine $\times 15$.

Micro-analysis.

- (i) 3.559 mgm. : 8.024 mgm. CO_2 and 2.261 mgm. H_2O .
 3.508 mgm. : 0.159 c.c. N_2 at 621 m.m. and 25.5°C .
 (ii) 3.740 mgm. : 8.400 mgm. CO_2 and 2.604 mgm. H_2O .
 3.749 mgm. : 0.167 c.c. N_2 at 625 m.m. and 23.5°C .

Found—

- (i) C = 61.49 per cent. ; H = 7.51 per cent. ; N = 4.24 per cent.
 (ii) C = 61.25 per cent. ; H = 7.79 per cent. ; N = 4.22 per cent.

Calculated for $\text{C}_{18}\text{H}_{27}\text{O}_6\text{N}$:

C = 61.18 per cent. ; H = 7.70 per cent. ; N = 4.0 per cent.

Therefore formula is $\text{C}_{18}\text{H}_{27}\text{O}_6\text{N}$.

Specific rotation:

- (a) weight = 50.0 mgm.
 volume = 10.0 c.c. ethanol.
 $\theta = -0.47^\circ$.
 $[\alpha]_D^{20} = -94^\circ$ (ethanol).

- (b) weight = 50.0 mgm.
 volume = 8.0 c.c. chloroform.
 $\theta = -0.75^\circ$.
 $[\alpha]_D^{20} = -120.0^\circ$ (chloroform).

Chemical Properties.

The alkaloid gave positive alkaloidal reactions with Wagner's and Dragendorff's reagents and with phosphotungstic and picric acid solutions. It gave *no* precipitate with Mayer's reagent.

The alkaloid tasted extremely bitter and dissolved readily in methanol, ethanol and chloroform; it dissolved sparingly in cold and hot acetone and dissolved in boiling water and ethyl-acetate. It was insoluble in ether and petroleum-ether. It dissolved readily in dilute mineral acid solutions and slowly decolourized soda-alkaline potassium permanganate solution.

Rosmarinine Nitrate.

400 mgm. Rosmarinine was dissolved in the calculated quantity of decinormal nitric acid and the solution allowed to evaporate in front of a fan at room temperature. The crystalline residue was recrystallized from absolute alcohol-ether and the colourless prismatic crystals melted sharply with decomposition at 218° C. (corr.).

Micro-analysis:

3.508 mgm.: 6.760 mgm. CO₂ and 2.103 mgm. H₂O
found: C = 52.49 per cent.; H = 6.71 per cent.

Calculated for C₁₈H₂₇O₆N.HNO₃:

C = 51.92 per cent.; H = 6.77 per cent.

Specific rotation:

weight = 100.0 mgm.; Vol. = 7.5 c.c. H₂O; $\theta = -1.22^\circ$.

$$[\alpha]_D^{20} = \frac{-1.22 \times 7.5 \times 1000^\circ}{1 \times 100}$$

$$= -91.5^\circ \text{ (conc. 1.33 per cent. H}_2\text{O)}.$$

In a further publication in this journal, the hydrolysis and other structural results of this alkaloid will be dealt with.

*List of Some of the Properties of the More Well-known and
Established Senecio Alkaloids.*

Name of Alkaloid.	Formula.	M.P. ° C.	$[\alpha]_D$.	M.P. of Nitrate.	$[\alpha]_D$ of Nitrate.
Senecionine.....	C ₁₈ H ₂₅ O ₆ N	232°	— 56.0 (CHCl ₃)	214°	—34.2 (water).
Retrorsine.....	C ₁₈ H ₂₅ O ₆ N	214°	— 17.6 (C ₂ H ₅ OH)	110°	—36.1 (water).
Isatidine.....	C ₁₈ H ₂₅ O ₆ N	138°	— 8.25 (water)	130°	—23.3 (water).
Platyphylline....	C ₁₈ H ₂₇ O ₆ N	129°	— 45.0 (CHCl ₃)	—	—
Rosmarinine.....	C ₁₈ H ₂₇ O ₆ N	208°	—120.0 (CHCl ₃) — 94.0 (C ₂ H ₅ OH)	218°	—91.5 (water).

These alkaloids have now all been isolated from certain species of *Senecio* in this laboratory. Rosmarinine, a new alkaloid, has so far been isolated from *S. rosmarinifolius* Linn. only. In addition to the isolation of Senecionine from *S. ilicifolius* Thunb. it has also been obtained from:—

Senecio vulgaris (Manske, 1936, Barger and Blackie, 1936).

Senecio viscosus (Manske, 1936, Barger and Blackie, 1936).

Senecio squalidus (Manske, 1936, Barger and Blackie, 1936).

Senecio aureus (Manske, 1939).

Platyphylline will be dealt with in due course.

SUMMARY.

I. Two of the main *Senecio* species responsible for "bread-poisoning" in human beings in the Cape South-Western districts, viz., *S. ilicifolius* Thunb. and *S. rosmarinifolius* Linn., have been chemically examined for their toxic principles.

II. From *S. ilicifolius* Thunb. a known alkaloid, Senecionine, $C_{18}H_{25}O_5N$, previously isolated by other workers from *S. vulgaris*, *S. viscosus*, *S. squalidus* and *S. aureus*, has been obtained.

III. Senecionine is a stable alkaloid with m.p. 232° and very sparingly soluble in water. The alkaloid will not be destroyed during the baking of bread from flour of contaminated wheat.

IV. *S. rosmarinifolius* Linn. contains a new alkaloid for which the name "Rosmarinine" is proposed. It has the formula $C_{18}H_{27}O_6N$, the melting-point 208° , it is extremely bitter and very sparingly soluble in water. It must be considered a dangerous poison when wheat becomes contaminated with *S. rosmarinifolius* or when animals graze on this plant.

V. Rosmarinine has a specific rotation of -120.0° in chloroform and -94.0° in ethanol. Its nitrate has a melting-point of 218° C. and a specific rotation of -91.5° in water.

VI. As a result of this chemical investigation and the nature of the toxic principles, the author urges the complete eradication of these *Senecio* plants which unfortunately occur very abundantly. This is considered the only remedy to prevent human deaths due to "bread-poisoning" and animal losses from chronic liver-cirrhosis.

LITERATURE.

- BARGER, G., AND BLACKIE, J. J. (1936). Alkaloids of *Senecio*, Part II. Senecionine and Squalidine. *J. Chem. Soc., Part I*, pp. 743-745.
- BARGER, G., AND BLACKIE, J. J. (1937). Alkaloids of *Senecio*, Part III. Jacobine, Jacodine and Jaconine. *J. Chem. Soc., Part I*, pp. 584-586.
- BLACKIE, J. J. (1937). The alkaloids of the genus *Senecio*. *The Pharm. Jnl.*, January 30, pp. 1-8.

- DE WAAL, H. L. (1939). The senecio alkaloids, Part I. The isolation of Isatidine from *Senecio retrorsus* and *Senecio isatideus*. *Onderstepoort Jnl. Vet. Sci. and An. Ind.*, Vol. 12, No. 1, pp. 155-163.
- DE WAAL, H. L. (1940). The Senecio alkaloids, Part II. Hydrogenation, hydrolysis and structural results of Isatidine. *Onderstepoort Jnl. Vet. Sci. and An. Ind.*, Vol. 14, Nos. 1 and 2, pp. 433-450.
- MANSKE, R. H. F. (1931). The alkaloids of Senecio species I. The Necines and Necic acids from *S. retrorsus* and *S. jacobaea*. *Canad. Jnl. Res.*, Vol. 5, pp. 651-659.
- MANSKE, R. H. F. (1936). The alkaloids of Senecio species II. Some miscellaneous observations. *Canad. J. Res.*, Vol. 14, pp. 6-11.
- MANSKE, R. H. F. (1939). The alkaloids of Senecio species III. *Senecio integerrimus*, *S. longilobus*, *S. spartioides* and *S. ridellii*. *Canad. J. Res.*, Vol. 17, pp. 1-7.
- ORECHOFF, A. P., AND TIEDEBEL, W. (1935). Ueber Senecio alkaloide I. Die Alkaloide von *Senecio platyphyllus* D.C. *Ber.* 68, pp. 650-655.
- STEYN, D. G. (1934). The toxicology of plants in South Africa. Cent. News Agency, S.A., Ltd.

The Senecio Alkaloids Part IV. Platyphylline, the Active Principle of *Senecio adnatus*, D.C.

By H. L. DE WAAL, Section of Pharmacology and Toxicology,
Onderstepoort, and J. TIEDT* of the University College,
Potchefstroom.

It is estimated to-day that approximately three hundred species of *Senecio* occur freely and often grow abundantly in South Africa. It is well known that many of these species, e.g., *S. retrorsus* D.C. and *S. isatideus* D.C. are the cause of acute or chronic seneciosis especially in horses, but also in cattle and sheep. *S. ilicifolius* Thunb. again is the cause of "bread poisoning" in human beings, whilst many other *Senecio* species are also suspected poisonous plants. Horse-breeding, especially, has suffered very severe losses in the past and many losses are still occurring in the Eastern Cape Province, in the Transkei and in Griqualand East. The following *Senecio* species, e.g., *S. retrorsus* D.C., *S. isatideus* D.C., *S. graminifolius* Jacq., *S. bunpleurioides* D.C., *S. pterophorus* D.C. and many others are definitely known to occur in these areas. The five species mentioned above, all contain toxic alkaloids (see de Waal, 1939, 1940 and in Press).

During an inspection tour through the above-mentioned areas in order to study the local *Senecio* species and the conditions of *Senecio* poisoning in stock, one of us and Dr. D. G. Steyn collected a few bags of another *Senecio* variety, viz., *S. adnatus* D.C. It grows in batches along water-streams and in sheltered mountain-valleys in the Griqualand East and Transkeian areas. Specimens of this plant were collected in the flowering stage on a farm, Slangfontein, about 7 miles from Kokstad, in the Mount Currie district. More specimens of the same species were collected at Sugarbush stream, which is about halfway between Mt. Ayliff and Mt. Frere on the main road from Kokstad to Umtata. The plant was identified by the Division of Botany and Plant Industry, Pretoria, as *S. adnatus* D.C.

S. adnatus is a vigorous grower under humid and sheltered conditions. It is a rigid, erect and herbaceous plant with elongate-lanceolate leaves and yellow flowers (see Fig. 1). The plants collected

* Thesis presented in partial fulfilment of the requirements for the M.Sc. degree in the University of South Africa.

for chemical investigation were gathered at Sugarbush stream in November, 1939, in the flowering stage. They were approximately 3 to 5 feet high. Animal losses cannot with certainty be attributed to the eating of this plant, as many other species and even more toxic varieties occur abundantly in these areas.

In this paper the results of the chemical investigations of this plant and of its active principle are recorded. The isolated active principle is an alkaloid which proved to be identical with the alkaloid, platyphylline. Platyphylline was previously isolated from *S. platyphyllus* D.C. (Orechoff, 1935) an indigenous species of the Transcaucasian areas.

S. adnatus D.C. is a typical member of the *Paucifolii* group (sub-section: *Lanigerosi*: C. A. Smith, unpublished) but unlike the members of this group so far investigated, it does not contain either retrorsin or isatidin (de Waal, 1939, 1940 and in Press), but the alkaloid platyphylline.

While *S. platyphyllus* contains two alkaloids, platyphylline and seneciophylline, *Senecio adnatus* contains only the former alkaloid. In the light of these investigations *S. adnatus* D.C. must henceforth be considered a poisonous species of the genus *Senecio*.

EXPERIMENTAL PART.

Seven kilograms of dried and ground *S. adnatus* D.C. were introduced into a large extractor and thoroughly extracted with about 10 gallons of 96 per cent. alcohol. When the extraction was complete the alcohol was distilled off under reduced pressure. To facilitate the removal of the last traces of alcohol a little water was added in the final stages of the distillation. The volume of the watery residue was measured and four equal portions of 1 liter each were decanted and treated separately and differently to ascertain the best procedure for the isolation of the active principle. The residual fraction was then treated according to the method which yielded the best results.

The four methods tried were as follows:—

Method 1.—One litre of the watery extract was acidified with a concentrated solution of citric acid until the solution was distinctly acid to litmus, shaken and allowed to settle for several days. The supernatant was then filtered and the filtrate thoroughly shaken with ether, followed by two small portions of chloroform. Air was then bubbled through the clear tawny acid solution to remove any ether and chloroform which might be present. The acid solution was then alkalified with a 5 per cent. ammonium hydroxide solution. The alkaline solution was thoroughly and repeatedly shaken with chloroform until no more substance was removed. The chloroform shakings were combined, washed once with water, concentrated on a steam-bath, dried over exsiccated sodium sulphate and allowed to evaporate in front of a fan at room temperature. The last traces of chloroform were removed by the addition of a small volume of methanol. The residue consisted of the alkaloid in crystalline form. Crude yield was 5.6 grams.

Method 2.—This method constituted exactly similar treatment of a second fraction with one exception only, namely, the alkalification of the citric acid solution with a dilute potassium hydroxide solution.

The crude alkaloidal yield was 5.5 grams.

Method 3.—The watery extract of one litre was acidified with an equal volume of 5 per cent. hydrochloric acid solution, well shaken and allowed to settle. The purification of the acid solution was again effected in the same way as described in the first method. The pure acid solution was made alkaline with a 5 per cent. ammonium hydroxide solution and the alkaline solution extracted with chloroform as in the first method. The extraction with chloroform, however, resulted in the formation of very troublesome emulsions, which could only be overcome by laborious filtration. This also applies to the last method.

The yield was 3.4 grams of alkaloid.

Method 4.—This extraction of the alkaloid was again similar to the process described in the third method except that the hydrochloric acid solution was made alkaline with a dilute potassium hydroxide solution.

Alkaloidal yield was 3.5 grams.

The first method gave the best results, resulting in the quickest and purest isolation of the alkaloid and yielding the highest amount of active principle, namely 5.6 grams. The residual watery extract was therefore treated according to the first method.

A careful examination of the alkaline solutions (see de Waal, 1939) after the extraction with chloroform showed that no alkaloid was present in these alkaline liquors.

The examination of the chloroform solutions resulted in the isolation of one alkaloid only, which was later identified as platyphylline (see below). Calculated on the basis of the best extraction method (method 1) *S. adnatus* D.C. in the flowering stage (see Fig. 1) contains 0.5 per cent. platyphylline in the dried plant material.

ISOLATION OF PLATYPHYLLINE.

The dry alkaloidal residues, after the evaporation of the chloroform, were dissolved in a small volume of ethanol, the ethanol solution decolorized with a small amount of charcoal and the filtrate allowed to evaporate to dryness. Preliminary experiments showed that the colourless crystalline residue after the evaporation of the ethanol could be crystallized from a hot 20 per cent. alcohol solution. After several recrystallizations from this solvent, the substance melted sharply and without decomposition at 129° C. (corr.)*. The alkaloid crystallized in large rhombic prisms (see Fig. 2).

* All melting-points were recorded with the Kofler micro-melting point apparatus and are therefore corrected.

Micro-analysis†

3.289 mgm.: 7.800 mgm. CO₂ and 2.371 mgm. H₂O.

5.127 mgm.: 0.242 c.c. N₂ at 26° C. and 625 m.m. Hg.

found: C=64.48 per cent.; H=8.04 per cent.; N=4.43 per cent.

Calculated for C₁₈H₂₇O₅N:

C=64.08 per cent.; H=8.06 per cent.; N=4.15 per cent.

A duplicate analysis confirmed the formula: C₁₈H₂₇O₅N.



Fig. 1.—*Senecio adnatus*, D.C.

Chemical Properties of the Alkaloid.

The isolated substance is an alkaloid and gave precipitates with Mayer's, Dragendorff's and Wagner's alkaloidal reagents and also with picric acid and phosphotungstic acid solutions. A solution of the alkaloid in 2½ cent. sodium carbonate solution readily decolourized potassium permanganate solution and the alkaloid also decolourized bromine water.

† All micro-analyses were carried out by Dr. O. G. Backeberg, of the University of Witwatersrand, to whom we wish to express our thanks.

Solubility.

The solubility of the alkaloid in organic solvents was very marked. It readily dissolved in cold acetone, ether, chloroform, ethyl-acetate, methanol, ethanol, benzene, toluene, acetic acid and acetic acid anhydride. It was practically insoluble in cold water but dissolved slowly in boiling water. It readily dissolved in dilute mineral acids and was practically insoluble in alkalis. The alkaloid had a very bitter taste.

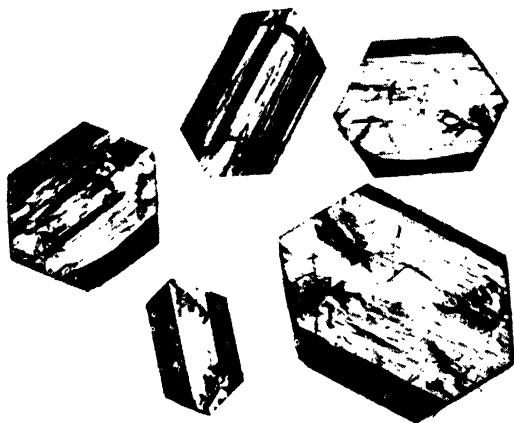


Fig. 2.—Platyphylline X 10 m.p. 129°.

Specific Rotation.

$[\alpha]_D^{25} = -59.0^\circ$ (conc. 4 per cent. in ethanol).

$[\alpha]_D^{25} = -56.4^\circ$ (conc. 2 per cent. in chloroform).

Orechoff (1935) recorded for the impure alkaloid, platyphylline, an $[\alpha]_D^{25} = -45.09^\circ$ in chloroform. Later in the same year Orechoff and Konowalowa (1935) corrected the formula from $C_{17}H_{23}O_5N$ for the impure alkaloid to $C_{18}H_{27}O_5N$ for the pure alkaloid but failed to improve the specific rotation.

Picrate Derivative.

A solution of 400 mgm. picric acid in 3 c.c. 96 per cent. alcohol (hot) was added to a solution of 500 mg. of alkaloid in 2 c.c. 96 per cent. alcohol (hot) and the two solutions gently mixed. After a

while the cloudy precipitate settled to the bottom of the tube as a sticky oily syrup. The supernatant was decanted and the precipitate boiled out with about 10 c.c. of ethanol. The bulk of the precipitate became crystalline and remained undissolved. The crystalline residue was then transferred to a boiling flask and refluxed with enough ethanol to effect complete solution. From the filtrate the picrate crystallized in yellow shining plates, which, when pure, melted at 199-200° C. It dissolved in cold water, hot ethanol, chloroform, acetone, ethyl-acetate and was slightly soluble in ether.

Micro-analysis.

3.620 mgm.: 6.832 mgm. CO₂ and 1.700 mgm. H₂O.

2.817 mgm.: 0.306 c.c. N₂ at 24.5 C. and 625 m.m. Hg.

found: C=51.47 per cent.; H=5.26 per cent.; N=9.90 per cent.

Calculated for C₁₈H₂₇O₅N.C₆H₃N₃O₇:

C=50.90 per cent.; H=5.33 per cent.; N=9.90 per cent.

A duplicate analysis confirmed the formula of



Perchlorate Derivative of the Alkaloid. (See Orechhoff et al, 1935.)

200 mgm. Alkaloid was dissolved in three times the theoretical amount of normal hydrochloric acid. Again 90 mgm. (theoretical amount plus 10 per cent.) sodium perchlorate was dissolved in just enough water to obtain a saturated solution. The two solutions were mixed in the cold and the perchlorate derivative of the alkaloid immediately crystallized out. It was recrystallized from hot water. The m.p. was 244-245° C.

Micro-analysis.

(i) 3.588 mgm.: 6.563 mgm. CO₂ and 2.056 mgm. H₂O.

(ii) 3.659 mgm.: 6.676 mgm. CO₂ and 2.042 mgm. H₂O.

found (i): C=49.89 per cent.; H=6.41 per cent.

,, (ii): C=49.75 per cent.; H=6.24 per cent.

Calculated for C₁₈H₂₇O₅N.HClO₄:

C=49.31 per cent.; H=6.44 per cent.

Therefore formula is C₁₈H₂₇O₅N.HClO₄.

It is clear from the analysis and properties of the alkaloid, of its picrate and of its perchlorate that it has the formula C₁₈H₂₇O₅N and is identical with the alkaloid platyphylline isolated from *S. platyphyllus* D.C. by Orechhoff (1935). This was also established by the isolation of the basic and acidic products of the hydrolysed alkaloid and their analyses and properties. Henceforth our active principle isolated from *S. adnatus* D.C. will be referred to as platyphylline.

Attempts to hydrogenate platyphylline catalytically in the presence of PtO_2 did not lead to a quantitative hydrogen absorption. Apparently a complex arrangement in the molecule impedes this reaction.

Hydrolysis of Platyphylline.

To 7.5 gms. platyphylline dissolved in the minimum quantity of ethanol was added 3.4 gms. solid potassium hydroxide (about 1.3 mol.) and the solution refluxed for one hour. The hydrolysed solution was then evaporated on a boiling waterbath almost to dryness and the residue dried in a vacuum desiccator over concentrated sulphuric acid.

The dry residue was then repeatedly extracted with dry acetone until the acetone gave no precipitate when treated with petroleum-ether.

Isolation of Platynecine.

The acetone solution was evaporated slowly when the base crystallized. The dry crystalline residue was dissolved in ethyl-acetate from which the base crystallized in small colourless plates. After a few recrystallizations from ethyl-acetate pure platynecine was obtained with a constant melting-point of 149°C . A soda-alkaline solution of the base decolourised potassium permanganate solution immediately and the base readily dissolved in water, methanol and ethanol.

Micro-analysis.

(i) 3.390 mgm.: 7.611 mgm. CO_2 and 2.892 mgm. H_2O .

3.836 mgm.: 0.353 c.c. N_2 at 625 m.m. Hg and 20°C .

(ii) 3.320 mgm.: 7.484 mgm. CO_2 and 2.831 mgm. H_2O .

3.354 mgm.: 0.316 c.c. N_2 at 624 m.m. Hg and 23°C .

found—

(i) C=61.23 per cent.; H=9.54 per cent.; N=8.92 per cent.

(ii) C=61.48 per cent.; H=9.54 per cent.; N=8.92 per cent.

Calculated for $\text{C}_8\text{H}_{15}\text{O}_2\text{N}$:

C=61.14 per cent.; H=9.55 per cent.; N=8.91 per cent.

Platynecine Picrate.

When the solution of the two components in absolute alcohol was mixed, the solution at first remained clear. The picrate was then precipitated with petroleum-ether and recrystallized with ethanol. The m.p. of the picrate was found to be $189\text{--}190^\circ\text{C}$. (corr.).

Micro-analysis.

Found: C=43.95 per cent.; H=4.91 per cent.

Calculated for $\text{C}_8\text{H}_{15}\text{O}_2\text{N} \cdot \text{C}_6\text{H}_3\text{N}_3\text{O}_7$:

C=43.53 per cent.; H=4.70 per cent.

Isolation of Platynecic Acid.

The resultant dry residue after the extraction of the base with acetone (see above) was acidified with conc. HCl (1 : 1) until distinctly acid to Congo-red. The solution which was then concentrated on a boiling waterbath until the crystals were about to separate, was filtered and the precipitate on the filterpaper washed with a few millimetres of boiling water. The moment the water reached the filtrate crystals separated. When the crystallization ceased the crystals were filtered off. On evaporation of the mother liquor some more of the same crystals were obtained. The joint crystalline material was extracted with ethyl-acetate which removed the acid from insoluble potassium salt. The ethyl-acetate was again evaporated and the residual crystalline acid recrystallized from benzene, from which it was obtained in the form of long silky needles (see Fig. 3). The pure acid was found to have the same melting-point as recorded by Orechhoff (1935) namely, 154°-155° C.

In alkaline solution it readily decolourized potassium permanganate solution.

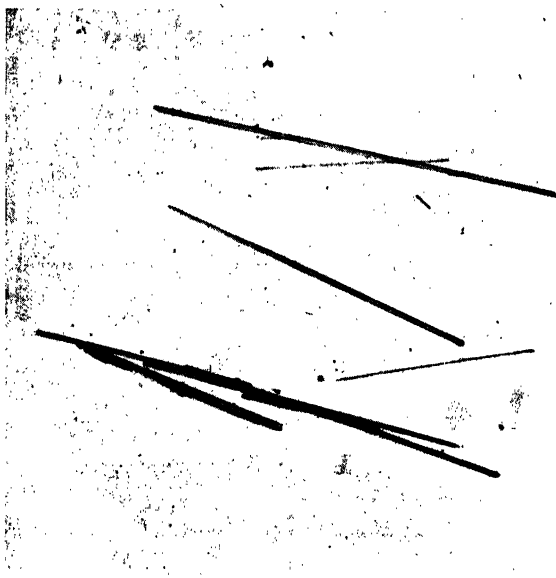


Fig. 3.—Platynecic acid X 14 m.p. 155°.

Micro-analysis.

Found: C=60.41 per cent.; H=7.02 per cent.

Calculated for $C_{10}H_{14}O_4$: C=60.60 per cent.; H=7.07 per cent.

The products of hydrolysis of platyphylline are therefore platynecine, $C_8H_{15}O_2N$, and platynecic acid $C_{10}H_{14}O_4$. The equation representing the hydrolysis is: $C_{18}H_{27}O_5N + H_2O = C_8H_{15}O_2N + C_{10}H_{14}O_4$.

These findings are in conformity with those of Orechhoff (1935), whose method of hydrolysis was, however, different to ours. The $[\alpha]_D^{25}$ of platynecic acid is $+45.0^\circ$ (Conc. 2 per cent. in ethanol), and not $+37.9^\circ$ as reported by Orechhoff on the less pure acid. In a next article to appear in this journal the structural nature of this acid will be discussed. Meanwhile the view is expressed that platynecic acid and senecic acid (Barger and Blackie, 1936) are eventually one and the same acid, a monolactonic, monocarboxylic and acyclic acid (and not a hydroxy acid, Orechhoff, 1935).

SUMMARY.

1. In this article are described the isolation of the alkaloid, platyphylline from *Senecio adnatus* D.C. as well as the preparation of some of its derivatives.

2. The alkaloid has the formula $C_{18}H_{27}O_5N$ and its fission products are platynecine, $C_8H_{15}O_2N$ and the monobasic platynecic acid, $C_{10}H_{14}O_4$. These findings are in conformity with those found for platyphylline from *S. platyphyllus* D.C. (Orechhoff, 1935).

3. The view is put forward with reserve that platynecic acid is identical with senecic acid and not a hydroxy acid as found by Orechhoff, but that the acid is a monolactonic, monobasic and acyclic acid.

4. *Senecio adnatus* D.C. must henceforth be considered toxic to stock as it contains at least 0.5 per cent. (calculated on the dried and ground plant) of the active principle platyphylline.

LITERATURE.

- BARGER, G., AND BLACKIE, J. J. (1936). Alkaloids of *Senecio*. Part II. Senecionine and Squalidine. *J. Chem. Soc.*, pp. 743-745.
- DE WAAL, H. L. (1939). The *Senecio* Alkaloids. Part I. The Isolation of Isatidine from *S. retrorsus* D.C., and *S. isatideus* D.C. *Onderstepoort J. Vet. Sci. and An. Ind.*, Vol. 12, pp. 155-163.
- DE WAAL, H. L. (1940). The *Senecio* Alkaloids. Part 3. Chemical Investigations upon the *Senecio* Species responsible for Bread-poisoning. The isolation of Senecionine from *S. ilicifolius* Thunb. and a New Alkaloid Rosmarinine from *S. rosmarinifolius* Linn. *Onderstepoort J. Vet. Sci. and An. Ind.* (this journ.).
- ORECHOFF, A. (1935). Ueber *Senecio* Alkaloide 1. Die Alkaloide von *Senecio platyphyllus* D.C. *Ber.*, Vol. 68, pp. 650-655.
- ORECHOFF, A., AND KANOWALOWA, R. (1935). Ueber *Senecio* Alkaloide 2. Zür Kenntnis des Platyphyllins. *Ber.*, Vol. 68, pp. 1886-1890.

Recent Investigations into the Toxicity of Known and Unknown Poisonous Plants in the Union of South Africa, X.

By S. J. VAN DER WALT and DOUW G. STEYN, Section
of Pharmacology and Toxicology, Onderstepoort.

(Continued from Onderstepoort Journal of Veterinary
Science and Animal Industry, Vol. 12, No. 2.)

ASCLEPIADACEAE.

Cryptolepis decidua N.E.Br.

(Figure 1.)

Registered No.: 156A; 31/3/39.

Common Name: —

Origin: Friedabrunn, Mariental, South West Africa.

State and Stage of Development: The plant was fairly wilted and in the late flowering and early seeding stages.

Sheep 52875 (4-tooth; 41.0 Kg.) was given* 500 gm. of the wilted plant at 3.45 p.m. on 5.4.39.

6.4.39; 8.30 a.m.: Apathy; pronounced laboured respiration (costo-abdominal); pulse fairly slow and strong; conjunctivae very red; ruminal movements in abeyance; anorexia; very pronounced diarrhoea.

6.4.39: 12 noon: The sheep was given another 250 gms. of the almost dry plant.

6.4.39: 2 p.m.: Very apathetic; breathing with the mouth open, expiration being very laboured; pulse extremely rapid, irregular and almost imperceptible; slight tympanites; clonic convulsions of the body muscles; general weakness; unable to support itself when lifted; marked cyanosis.

The sheep died at 3.30 p.m. the head being pulled back with the limbs extended and showing clonic convulsions.

* All animals are dosed by means of a stomach tube.



Fig. 1.—*Cryptolepis decidua* N.E.Br.

Post-mortem Appearances.—Pronounced general cyanosis; slight tympanites of the rumen; pronounced hyperaemia with slight atelectasis of the lungs; congestion of the liver and kidneys; few hyperaemic areas in the ruminal wall; slight hyperaemia of the abomasum; slight acute catarrhal duodenitis.

Histology.—Congestion of the kidneys, myocardium, spleen and liver. Fatty changes were noted in the latter organ.

CACTACEAE.

Opuntia sp.

Registered Number: O.P.H. No. 31730; 26.1.39.

Common Name: Prickly pear, turksvy.

Origin: Guchab, South West Africa.

State and Stage of Development: The plant was in the fresh state without flowers or fruit.

Using the method of Rimington and Steyn (1933) the fresh leaves were found to contain 11.7 per cent. oxalates calculated as oxalic acid on the dry weight basis. The moisture content equalled 91.85 per cent. The leaves were suspected of having caused poisoning in pigs.

COMPOSITAE.

Cryptostemma calendulaceum R.Br.

(Figure 2.)

Registered Number: O.P.H. No. 24396; 25.10.38.

Common Name: —

Origin: Grahamstown, Cape Province.

State and Stage of Development: The plant was in the dry state and in the flowering stage.

Rabbit A (1.95 Kg.) was given, at 11 a.m. on 2.11.38, the juice expressed from 50 gm. of the plant.

2.11.38: 3 p.m.: Paresis had set in, the animal, however, still struggling when handled. The respiration was rapid and shallow whilst the heart beat was imperceptible and the conjunctivae pale.

Within ten minutes the head slowly dropped to the floor of the cage. At first the animal was able to lift its head but was unable to keep it up with the result that it slowly dropped to the floor of the cage. However, within a few minutes complete paralysis had set in.

At this stage the corneal and pupillary reflexes were decreased and the animal was insensitive all over its body and extremities to pinpricks. Finally convulsions, probably asphyxia, accompanied by "crying" set in. The respiration was extremely laboured whilst



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NATIONAL HERBARIUM, PRETORIA
Not Herb. No. Regio. Transvaal, G. P.
Cryptostemma calendulaceum R. Br.
C. G. G. G.
AB. Anno May 1911 Regio. Transvaal
No. 1, 1911

Fig. 2.—*Cryptostemma calendulaceum* R.Br.

undulations of the abdominal wall caused by intestinal peristalsis were observed. The pupils became widely dilated and the animal died at 3.30 p.m. on 2.11.38.

Post-mortem Appearance.—General cyanosis; slight hydro-peritoneum; heart dilated; congestion and marked emphysema of both lungs; degeneration and congestion of the kidneys and liver; tympanites of the stomach with marked hyperaemia of the mucosa of the stomach and small intestine, the contents of the latter being haemorrhagic and containing cylinders of fibrin; hyperaemia of the mucous membrane of the urinary bladder.

Rabbit B (1.45 Kg.) was given the juice expressed from 55 gm. of the plant in two doses in the course of 24 hours on 2.11.38 and 3.11.38.

The animal died overnight on 3.11.38.

Post-mortem Appearances.—Abdomen very distended; general cyanosis; hydrothorax; heart dilated; emphysema of both lungs with an area of consolidation in the left lung (aspiration of material); pronounced tympanites of the stomach with hyperaemia and necrosis of the mucous membrane of the stomach; congestion of the liver and kidneys.

The narcotic action of the active principle(s) of the plant supports the claim of the sender that the juice expressed from the crushed or minced plant mixed with milk is an antidote for strychnine poisoning.

Gnaphalium luteoalbum Linn.

Registered Number: O.P.H. No. 24942A; 31.10.38.

Common Name: Cud weed, "roerkruid".

Origin: Lake Chrissie.

State and stage of development: The plant was fairly fresh and in the early flowering stage.

Sheep 51758 (6-tooth; 41.5 Kg.) was given 2.3 Kg. of the plant in the course of 30 hours.

Result: Negative.

Helichrysum cephaloideum D.C. var. *adscendens*.

(Figure 3.)

Registered number.—O.P.H. No. 24368, 24.10.38; and 24701-02, 27.10.38.

Common name:—

Origin: Bathurst, Cape Province.

State and stage of development: The plant was in the dry state and in the flowering stage.



Fig. 3.—*Helichrysum celphaloideum* D.C. var. *adscendens*.

Sheep 52109 (4-tooth; 39.0 Kg.) was given 600 gm. of the dry plant on 2.11.38.

3.11.38: Anorexia; apathy; diuresis; decreased activity of the rumen; accelerated pulse and respiration; diarrhoea.

4.11.38: As for the previous day except that the ruminal movements were in abeyance.

6.11.38-20.11.38: Diarrhoea had ceased and was followed by severe constipation.

21.11.38: The sheep died after subcutaneous administration of 0.5 c.c. Lentin.

Post-mortem appearances.—Fairly marked post-mortem changes: general cyanosis; hyperaemia and oedema of both lungs; stasis of ingesta throughout the alimentary tract; hyperaemia of the abomasum and small intestine; fat necrosis.

CUCURBITACEAE.

Kedrostis nana Cogn.

(Figure 4.)

Registered number: O.P.H. No. 34226. 14.3.39; and 2674, 16.6.39.

Common name:—

Origin: Cape Town, Cape Province.

State and stage of development: The plant was in the fresh state without flowers or fruit.

Sheep 51158 (4-tooth; 25.5 Kg.) was given 700 gm. of the dried plant (O.P.H. No. 2674; 16.6.39) in the course of 5 hours on 20.6.39.

21.6.39: The Animal had developed a slight diarrhoea.

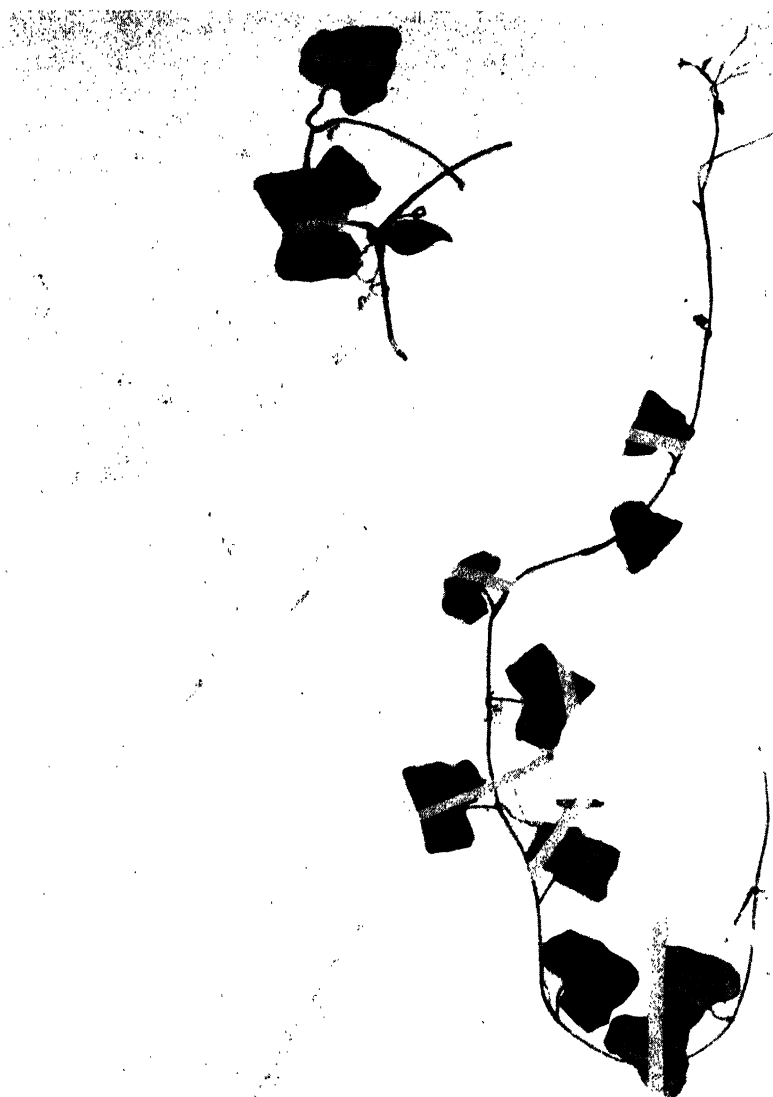
22.6.39: Recovered.

Sheep 51364 (4-tooth; 20.5 Kg.) was given 2.4 Kg. of the fresh tubers in the course of 24 hours on 20.6.39 and 21.6.39.

21.6.39: The animal had developed a slight diarrhoea.

22.6.39: Recovered.

Rabbit A (1.4 Kg.) was given 120 c.c. of the juice expressed from the tubers of the first consignment of the plant (O.P.H. No. 34226; 14.3.39). Two hours after receiving the above dose the following symptoms were observed in the animal: Pupils dilated; heartbeat imperceptible; "crying"; convulsions; undulations of the abdominal wall caused by very active peristalsis of the intestines. The animal died 10 minutes later.



R. MARLOTH
FLORA AFRICAE AUSTRALIS.

Kedrostis nana Cogn.

Fig. 4.—*Kedrostis nana* Cogn.

Post-mortem appearances: General cyanosis; congestion and slight emphysema of both lungs; congestion of, and regressive changes in, the liver and kidneys; severe hyperaemia of the mucosa of the stomach; fairly marked hyperaemia of the mucosa of the small intestine.

The following rabbits were drenched with the pulped tubers of the second consignment of the plant (O.P.H. No. 2674; 16.6.39).

Rabbit B (1.4 Kg.) was given 30 gm. of the fresh tubers.

Thirty minutes later the animal was lying down, the heart action was weak and the respiration very laboured. Death occurred five minutes later.

Post-mortem appearances: Marked emphysema and hyperaemia of both lungs with occasional haemorrhages; severe hyperaemia of, and several haemorrhagic areas in, the gastric mucosa; severe hyperaemia of the mucosa of the small intestine, the contents being haemorrhagic.

Rabbit C (1.8 Kg.) was given 15 gm. of the fresh tubers. The animal died overnight.

Post-mortem appearances.—As for Rabbit B, except that necrotic changes were observed in the gastric mucosa and that the region of the anus was soiled by diarrhoeic faeces.

Rabbit D (2.7 Kg.) was given 7.5 gm. of the fresh tubers

Symptoms.—Six hours after drenching, the rabbit was found paralysed with rapid superficial respiration, the heartbeat being imperceptible. A large quantity of fluid faeces had been passed. The rabbit died 15 minutes later

Post-mortem.—As for the previous rabbit.

Rabbit E (1.85 Kg.) was given 3.5 gm. of the fresh tubers on 26.6.39.

27.6.39: Anorexia.

28.6.39: Feeding and altogether normal.

EUPHORBIACEAE.

Croton megalobotrys Nüll.Arg.

Registered number: O.P.H. No. 33174; 22.2.39.

Common name:—

Origin: Dennilton, Pretoria.

State and stage of development: The plant was in the fresh state with maturing fruit.

Rabbit A (1.5 Kg.) was given the juice expressed from 255 gm. of the fruit in the course of 24 hours.

Result: Negative.

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Rabbit B (1·7 Kg.) was given in one dose the juice expressed from 30 gm. of the leaves.

Result: Negative.

Euphorbia glauccella D.C.

Registered number: O.P.H. No. 156B; 5.4.39.

Common name:—

State and stage of development: The plant was wilted and in the early seeding stage.

Origin: Friedabrunn, Mariental, South West Africa.

Rabbit A (2·2 Kg.) was given 30 gm. of the plant in the course of 18 hours.

Result: Negative.

Rabbit B (2·4 Kg.) was given 60 gm. of the plant in the course of 18 hours.

Result: Negative.

Euphorbia sp. nearest *E. pubescens* Vahl.

Registered number: O.P.H. No. 10417; 9.12.39.

Common name:—

Origin: Hartbeestpoort Experimental Farm, Transvaal.

State and stage of development: The plant was in the fresh state and in the flowering stage.

Sheep 51420 (6-tooth; 43·2 Kg.) was given 6·2 Kg. of the fresh and wilted plant in the course of 9 days.

Result: Negative.

Jatropha capensis Sond.

Registered number: O.P.H. No. 30283; 12.12.38.

Common name:—

Origin: Grahamstown, Cape Province.

State and stage of development: The plant was almost dry and without flowers or fruit.

Sheep 50397 (2-tooth; 37·5 Kg.) was given 600 gm. of the dry plant in the course of 5 hours.

Result: Negative.

The plant was found to yield 0·15 mgm. hydrocyanic acid per 100 gms.

GRAMINEAE.

Paspalum distichum Linn.

Registered Number: O.P.H. No. 1447; 15.5.39.

Common name: Buffalo-kweek.

Origin: Grahamstown, Cape Province.

State and stage of development: The plant was in the dry state and in the late seeding stage. The seed heads were infected by *Claviceps paspali*.

Sheep 51364 (4-tooth; 19.3 Kg.) was given 6.8 Kg. of the fungus-infected grass in the course of 6 days.

Result: Negative.

IRIDACEAE.

Moraea setacea Ker.

(Figure 5.)

Registered number: O.P.H. No. 34235; 14.3.39.

Common name: "tulp", blue tulip, "blou tulp", "bokuintjie".

Origin: Ixopo, Natal.

State and stage of development: The plant was in the dry state and in the post-seeding stage. The bulbs of the plant were, however, still fairly fresh.

Sheep 52052 (6-tooth; 39.0 Kg.) was given 1.2 Kg. of the bulbs in the course of 3 hours on 14.3.39.

The animal died at approximately 8 p.m. on 14.3.39. When seen at 11 p.m. on 14.3.39 the abdomen was fairly distended.

Post-mortem appearances.—Advanced post-mortem changes: general cyanosis; petechiae in the thymus; marked hyperaemia and oedema of both lungs with froth in the air passages; slight hydrothorax and hydropericardium; slight hyperaemia of the mucosa of the caecum.

Rabbit A (1.2 Kg.) was given 90 gm. of the bulbs on 27.3.39.

The animal died during the night of 27.3.39.

Post-mortem appearance.—Fairly marked post-mortem changes; general cyanosis; fairly marked emphysema of both lungs; congestion of the liver and kidneys; stomach fairly distended; slight hyperaemia of the mucosa of the stomach.

Sheep 50524 (4-tooth; 40.0 Kg.) was given 400 gm. of the dried leaves.

Result: Negative.

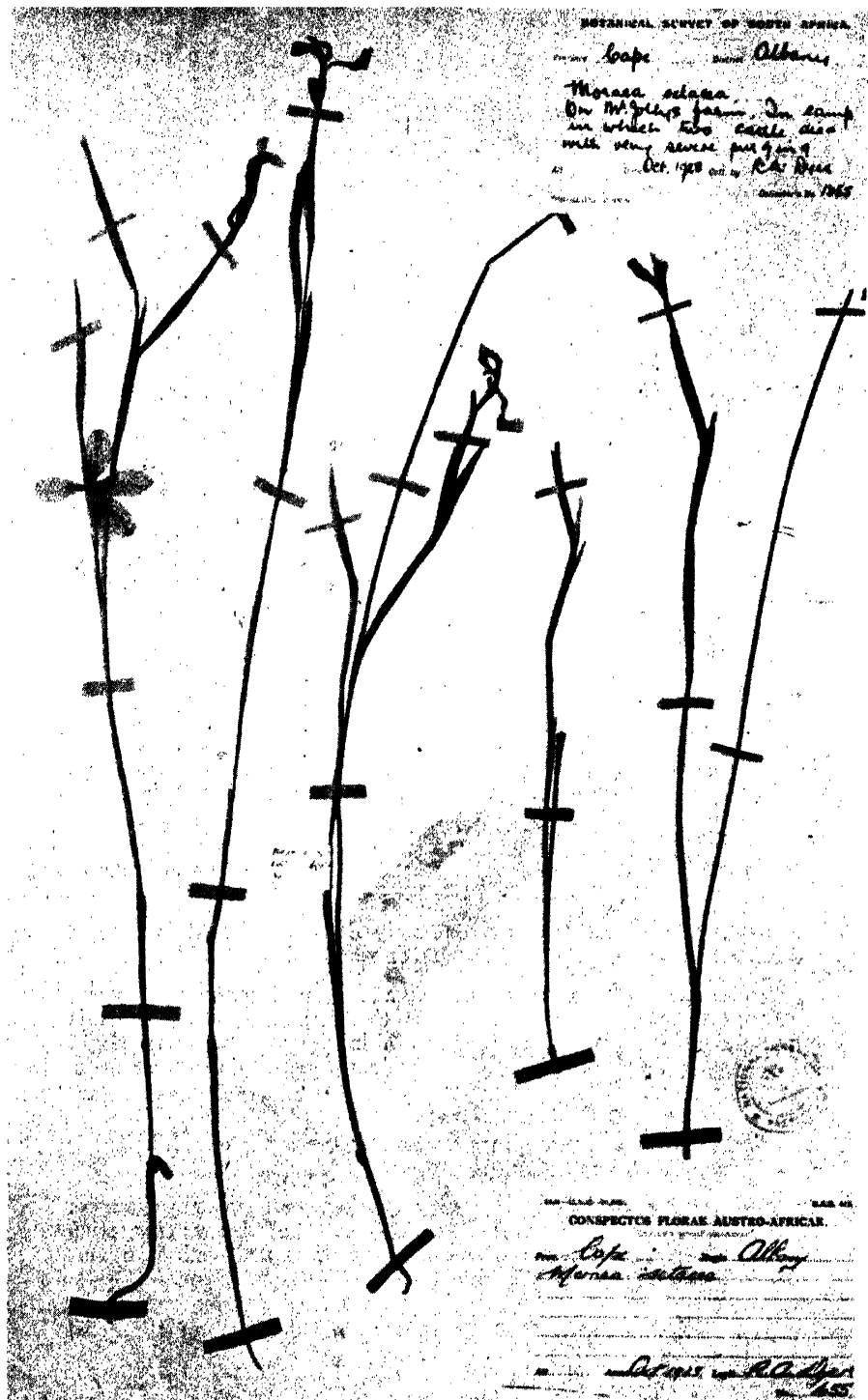


Fig. 5.—*Moraea setacea* Ker.
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LABIATAE.

Leonotis leonurus R. Br.

Registered number: O.P.H. No. 1915; 30.5.39.

Common name: Wilde dagga.

Origin: Grahamstown, Cape Province.

State and stage of development: The plant was in the dry state and in the flowering stage.

Pig 71 (2 months old; 34.1 Kg.) was fed 520 gm. of the dry plant mixed with bran in the course of 2½ days.

Result: Negative.

LILIACEAE.

Bulbine longiscapa Wild.

Registered number: O.P.H. No. 5760; 7.9.39.

Common name:—

Origin: Grahamstown, Cape Province.

State and stage of development: The plant was in the fresh state and in the early flowering stage.

Sheep 51451 (6-tooth; 32.8 Kg.) was given 4.0 Kg. of the fresh plant in the course of 30 hours.

Result: Negative.

Bulbine namaensis Schinz.

Registered number: O.P.H. No. 1389; 12.5.39.

Common name:—

Origin: Outjo, South West Africa.

State and stage of development: The plant was in the dry state without flowers or fruit.

Sheep 51753 (4-tooth; 18.4 Kg.) was given 650 gm. of the dry plant in the course of 4 hours.

Result: Negative.

Bulbine narcissifolia Salm. Dyck.

Registered number: O.P.H. No. 7265; 6.10.39.

Common name: Wilde kopieva.

Origin: Kokstad, Cape Province.

State and stage of development: The plant was in the fresh state and in the flowering stage.

TOXICITY OF KNOWN AND UNKNOWN POISONOUS PLANTS.

Sheep 51158 (6-tooth; 40·0 Kg.) was given 2·8 Kg. of the fresh plant in the course of 30 hours.

Result: Negative.

Ornithogalum subulatum Bkr.

Registered number: O.P.H. No. 6530; 22.9.39.

Common name:—

Origin: Swellendam, Cape Province.

State and stage of development: The plant was in the fresh state without flowers or fruit.

Rabbit A (3·4 Kg.) was given 120 gm. of the fresh plant in the course of 30 hours.

Result: Negative.

POLYGONACEAE.

Rumex acetosella Linn.

Registered number: O.P.H. No. 8319; 30.10.39.

Common name: Dock, sheep sorrel, sour dock, “boksuring” and “steenboksuring”.

Origin: Oorsprongberg, Orange Free State.

State and stage of development: The plant was in the dry state and in the seeding stage.

Sheep 51158 (6-tooth; 37·3 Kg.) was given 1·0 Kg. of the dry plant in the course of 2 days.

Result: Negative.

SOLANACEAE.

Solanum macrosolum Fern.

Registered number: O.P.H. 11694-96; 11.1.40.

Common name: “Bitterappeltjies”.

Origin: Krugersdorp, Transvaal.

State and stage of development: The plant was in the fresh state with immature and mature fruit.

Rabbit A (1·35 Kg.) was given in the course of 4 hours the juice expressed from 400 gm. immature fruit.

Result: Negative.

Rabbit B (3·2 Kg.) was given in the course of 5 hours the juice expressed from 400 gm. mature fruit.

Result: Negative.

Solanum quadrangulare Thunb.

Registered number: O.P.H. No. 1916; 30.5.39.

Common name:—

Origin: Grahamstown, Cape Province.

State and stage of development: The plant was in the dry state, somewhat mouldy and without flowers or fruit.

Pig 73 (2 months old; 36·8 Kg.) consumed 430 gm. of the dry plant in the course of 2½ days.

Result: Negative.

SANTALACEAE.

Thesium namaquense Schltr.

Registered number: O.P.H. No. 5740; 7.9.39.

Common name:—

Origin: Richmond, Cape Province.

State and stage of development: The plant was in the dry state without flowers or fruit.

Sheep 52743 (6-tooth; 27·5 Kg.) was given 600 gm. of the dry plant in the course of 7 hours on 11.9.39.

11.9.39: 4 p.m. Apathy, slight tympanites; atony of the rumen; accelerated pulse and laboured respiration; expiration accompanied by groaning; conjunctivae red; slight paresis of the hindquarters.

The animal died during the night of 11.9.39.

Post-mortem appearances.—Advanced post-mortem changes; general cyanosis; tympanites of the rumen; petechiae in the epicardium; hyperaemia and oedema of both lungs.

VITACEAE.

Cissus sp.

(Figure 6.)

Registered number: O.P.H. No. 99A; 5.4.39.

Common name:—

Origin: Karibib, South West Africa.

State and stage of development: The plant was in the fresh state without flowers or fruit.

Rabbit A (1·4 Kg.) was given 20 gm. of the fresh leaves.

Result: Negative.

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Rabbit B (2.24 Kg.) was given 20 gm. of the fresh leaves.

Result: Negative.

Using the method of Rimington and Steyn (1933) the oxalate content of the fresh leaves of the plant was found to be 7.19 per cent. calculated as oxalic acid on the dry weight basis. The moisture content of the fresh leaves was 88.14 per cent.



Fig. 6.

In the course of investigating the poisonous plant problem in South West Africa in 1937 one of us (D.G.S.) had a most unfortunate experience with this plant growing in the mountains near Omaruru. A portion of the leaf, approximately the size of a sixpence, was chewed and the juice swallowed. Within a few minutes there was in the mouth and throat a sensation which is very difficult to describe. It was a kind of sensation of burning associated with a state of spasm of the pharynx which rendered the act of swallowing almost impossible. Attempts to swallow were immediately followed by a kind of retroperistalsis in the upper portion of the oesophagus. The sensation of burning spread down into the stomach. Taking food or drink was most uncomfortable for quite a number of days on account of the tenderness of the mucous membrane of the pharynx, oesophagus and stomach, and also because of the retroperistalsis in

the oesophagus. The above symptoms lasted for approximately two weeks. It is surprising that such a small portion of the leaf could produce such pronounced symptoms.

SUMMARY.

The toxicity of 22 plants was investigated. According to the available literature the following five of these plants were proved for the first time to be toxic: *Cryptolepis decidua* N.E.Br., *Cryptostemma calendulaceum* R.Br., *Helichrysum cephaloideum* D.C. var *adscendens*, *Kedrostis nana* Cogn. and *Moraea setacea* Ker.

ACKNOWLEDGMENTS.

Our thanks are due to Dr. E. P. Phillips, Principal Botanist, Division of Plant Industry, Pretoria, and to Mr. A. O. D. Mogg, Dr. R. A. Dyer and Miss Verdoorn, botanists in the Division of Plant Industry, for the identification of the plant specimens. To Mr. R. Clark of the Section of Pathology, Onderstepoort, we are indebted for the histological examination of animal organs. We also wish to thank Mr. M. G. van Niekerk for assistance rendered in the course of the experiments.

REFERENCE.

- RIMINGTON, C., AND STEYN, D. G. (1933). *Psilocaulon absimile* N.E.Br. as Stock Poison I. Determination of oxalic, malic, tartaric acids, etc. *Onderstepoort Jnl. Vet. Sc. and An. Ind.*, Vol. 1 pp. 439-455.

Section IV.

Surgery and Obstetrics.

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QUINLAN, J., AND STEYN, H. P.	The influence of oöphorectomy on the performance of greyhound bitches 281

The Influence of Oöphorectomy on the Performance of Greyhound Bitches.

By J. QUINLAN and H. P. STEYN, Section of Surgery,
Onderstepoort.

GREYHOUND racing is a form of sport new to this country. It was started only seven years ago in Johannesburg. A number of dogs of both sexes were introduced from England and Ireland and ran on the only racing track in the country at that time. The sport developed rapidly under the direction of the African Greyhound Racing Association. It became so popular that a second club was soon formed, also in Johannesburg. The Manager of the latter club, The Union Greyhound Racing Association, Major Budd, began breeding greyhounds on a large scale. He had long been associated with greyhound racing and breeding in England before coming to South Africa. A number of well bred young bitches were purchased in England, and after having competed in races for a short time these were put to stud to form a nucleus for the breeding kennels. When the pups were growing the Manager discussed the problem of the females with us. The rules of the club prohibited bitches from racing for 3 months after they had shown "heat". This meant that they could be used only for 6 months in the year. The Manager considered this enforced biannual rest of the females uneconomic and the operation of oöphorectomy was suggested. Major Budd assured us that the operation had not been tried in England on racing bitches and so far as he was aware oöphorectomised bitches had not raced in England. As a number of bitches of suitable ages were available at the kennels of the Union Greyhound Racing Association it was decided to operate on some of them at once. In selecting females for operation it was decided to pick them from litters where litter sisters could be left unoperated upon for later comparison. The selection was done entirely by Major Budd. He selected the least promising bitches for operation as it was intended to breed from the others when they were retired from the race track. The age at which the operation was performed was between six and twelve months. The total number operated upon was thirty-six. Unfortunately there was an acute outbreak of distemper in the kennels during 1938 and only a few of the bitches survived. Several of those operated upon later are only now reaching maturity. However, the number that have reached racing age is considered sufficient to warrant a preliminary publication.

THE OPERATION.

The bitch is prepared by starving for 12 to 18 hours. During this period the ventral surface of the abdomen is shaved from the xyphoid cartilage to the pubis. It is afterwards painted with tincture of iodine. An hour prior to operation eukodal, 1 c.c. per 5 to 6 Kilos body weight, is given subcutaneously. Anaesthesia is completed with pernocton, approximately 0.2 to 0.3 c.c. per Kilo body-weight, given intravenously through the dorsal metatarsal vein just prior to operation.

The pernocton is given slowly, about 1 c.c. per minute. If care is taken in the rate of administration, the animal just reaches deep anaesthesia as the recommended dose is completed, and any undesirable effects the anaesthetic itself may have are eliminated. The patient is placed in the dorsal position with the head slightly lower than the body. The site of the operation is cleaned with aether, followed by tincture of iodine. The whole body is covered by sterile cloths through which an elliptical window has been made. The incision is made along the middle line, beginning half an inch in front of the umbilical cicatrix and extending about $1\frac{1}{2}$ inches behind it. If the tissues are severed along the linea alba there is little haemorrhage. When the peritoneum is reached it is picked up in a forceps and severed throughout the entire length of the wound with a straight blunt pointed scissors. Sterile gauze cloths are now fixed around the abdominal opening. The posterior extremity of the patient is raised from the table so that the intestines move forward, thereby allowing a clear view of the posterior abdominal cavity. The wound is dilated and by using a forehead lamp the uterus is easily seen running forward and outwards along the dorso-lateral surface of the abdomen. Both horns are picked up in slender forceps and the right withdrawn. Two catgut ligatures are tied on the ovarian ligament which is held in an artery forceps. The fallopian tube is then sectioned after which the ovary is removed with blunt pointed scissors. Before releasing the ovarian ligament the stump is carefully observed for haemorrhage. The left ovary and tube are now treated in a similar manner. The ovarian ligament in the greyhound bitch is exceedingly short, especially the left. This is further exaggerated by great chest development, so that the placing of ligatures on the ovarian ligament sometimes requires patience. The abdominal wound is closed in three layers with catgut. It is protected by a pad of loosely rolled gauze held in position by three or four transverse sutures through the skin. Immediately after the operation the patient is placed in a suitable jacket which prevents interference with the wound. Anaesthesia usually lasts 4 to 6 hours. Daily observations are made and the sutures removed from the fifth to seventh day.

With the exception of being submitted to the operation all the bitches received similar treatment from birth. There have been no differences between the sterilised and non-sterilised bitches, either in training or racing performance, except that two of the former have shown a tendency to put on two or three pounds in weight at certain periods. For instance, Girl Friend (Table 2, No. 11), whose best racing weight has been assessed at 48½ pounds, suddenly went up to

51½ pounds and showed a slight loss of form. Despite increasing her training work, and reducing her diet, this bitch could not be brought down to her normal racing weight. "Army Beauty" (Table 2, No. 9), who was best at about 50½ pounds, recently went up to 52 pounds, and has not run quite so well as previously. Great difficulty has also been found in reducing this bitch's weight. Apart from these few instances oöphorectomised and normal bitches do not appear to differ in any way except that the former have never shown any symptoms of "heat".

A perusal of the following tables showing the racing performances of six normal bitches and twelve oöphorectomised litter sisters indicates that the racing potentialities of greyhounds is not interfered with when the ovaries are removed between the ages of six and twelve months.

TABLE 1.

The following are the racing performances of non-sterilised bitches running at Wembley Stadium:—

Lanard Lass; Comrade O'Grady—Lady Jester, March, 1938. (Litter sister to Miss O'Grady, Table 2, No. 3).

1939—		
August, 23.....	325 yards.....	2nd in 19.63 seconds.
September, 6.....	325 yards.....	4th in 19.46 seconds.
1940—		
January, 10.....	525 yards.....	2nd in 31.94 seconds.
January, 17.....	325 yards.....	1st in 19.59 seconds.
January, 24.....	525 yards.....	2nd in 31.78 seconds.
January, 31.....	525 yards.....	2nd in 31.62 seconds.
February, 7.....	325 yards.....	1st in 19.02 seconds.
February, 14.....	525 yards.....	3rd in 31.79 seconds.
February, 21.....	325 yards.....	5th in 19.63 seconds.
February, 28.....	525 yards.....	5th in 31.90 seconds.
March, 6.....	525 yards.....	4th in 32.05 seconds.

African Lily; Hell's Bells—Ida's Lily, May, 1938. Litter sister to Black Magic and Military Maid, Table 2, Nos. 1 and 5).

1939—		
November, 29.....	325 yards.....	5th in 20.23 seconds.
December, 6.....	325 yards.....	2nd in 19.69 seconds.
December, 20.....	325 yards.....	4th in 19.93 seconds.
1940—		
January, 10.....	325 yards.....	2nd in 19.25 seconds.
January, 17.....	325 yards.....	2nd in 19.77 seconds.
January, 24.....	325 yards.....	3rd in 19.15 seconds.
January, 31.....	325 yards.....	3rd in 19.31 seconds.
February, 7.....	325 yards.....	6th in 19.51 seconds.
February, 14.....	325 yards.....	2nd in 19.31 seconds.
February, 21.....	325 yards.....	1st in 19.46 seconds.
February, 28.....	325 yards.....	5th in 19.27 seconds.
March, 6.....	325 yards.....	5th in 19.48 seconds.
March, 13.....	325 yards.....	4th in 19.25 seconds.

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Enchantress; Hell's Bells—Kilnafarna Lass, July, 1937. (Litter sister to Lady Make believe, Table 2, No. 6).

1939—		
May, 17.....	325 yards.....	5th in 20·12 seconds.
May, 24.....	325 yards.....	5th in 19·56 seconds.

Golden Jubilee; Brigadier—Lady Jester, December, 1936. (Litter sister to Girl Friend, Table 2, No. 11).

1938—		
March, 23.....	525 yards.....	3rd in 32·30 seconds.
March, 30.....	525 yards.....	1st in 31·47 seconds.
April, 6.....	525 yards.....	1st in 31·24 seconds.
April, 13.....	525 yards.....	Fell.
April, 20.....	525 yards.....	4th in 31·42 seconds.
April, 27.....	525 yards.....	6th in 31·95 seconds.
May, 4.....	525 yards.....	3rd in 31·34 seconds.
May, 11.....	525 yards.....	2nd in 31·19 seconds.
May, 18.....	525 yards.....	5th in 31·51 seconds.
May, 25.....	525 yards.....	3rd in 31·20 seconds.
June, 1.....	525 yards.....	2nd in 31·12 seconds.
June, 8.....	525 yards.....	1st in 30·62 seconds.
June, 22.....	525 yards.....	4th in 31·24 seconds.
June, 29.....	525 yards.....	6th in 31·01 seconds.
July, 6.....	525 yards.....	5th in 31·59 seconds.
July, 13.....	525 yards.....	2nd in 30·87 seconds.
July, 27.....	525 yards.....	4th in 31·60 seconds.
August, 10.....	525 yards.....	4th in 31·45 seconds.
August, 17.....	525 yards.....	3rd in 31·34 seconds.
August, 24.....	525 yards.....	1st in 31·40 seconds.
September, 7.....	525 yards.....	2nd in 31·40 seconds.
September, 14.....	525 yards.....	3rd in 31·22 seconds.
September, 21.....	525 yards.....	2nd in 31·34 seconds.
September, 28.....	525 yards.....	2nd in 31·36 seconds.
October, 5.....	525 yards.....	1st in 30·77 seconds.
October, 12.....	525 yards.....	1st in 30·72 seconds.
October, 19.....	525 yards.....	5th fell.
October, 23.....	525 yards.....	6th in 31·03 seconds.
November, 2.....	525 yards.....	1st in 30·71 seconds.
November, 9.....	525 yards.....	5th in 31·16 seconds.
November, 16.....	525 yards.....	2nd in 31·27 seconds.
November, 23.....	525 yards.....	1st in 30·77 seconds.
November, 30.....	525 yards.....	4th in 30·60 seconds.
December, 14.....	525 yards.....	3rd in 30·85 seconds.
December, 21.....	525 yards.....	5th in 31·01 seconds.
December, 28.....	525 yards.....	5th in 31·03 seconds.
1939—		
January, 4.....	525 yards.....	3rd in 30·81 seconds.
January, 11.....	725 yards.....	4th in 44·29 seconds.
January, 18.....	525 yards.....	4th in 30·84 seconds.
January, 25.....	525 yards.....	4th in 30·95 seconds.
February, 1.....	725 yards.....	1st in 43·53 seconds.
February, 8.....	525 yards.....	3rd in 31·30 seconds.
February, 15.....	525 yards.....	5th in 31·59 seconds.
March, 5.....	525 yards.....	6th in 31·18 seconds.
March, 12.....	525 yards.....	5th in 31·26 seconds.
March, 15.....	525 yards.....	6th stopped.
March, 20.....	525 yards.....	5th in 31·66 seconds.
March, 17.....	525 yards.....	5th broke down.

Sister Susie; Brigadier—Rolling Pin, August, 1938. (Litter sister to Cookhouse Call, Table 2, No. 7).

1939—		
December, 13.....	325 yards.....	6th in 19·80 seconds.
December, 20.....	325 yards.....	1st in 19·12 seconds.
December, 27.....	325 yards.....	4th in 19·62 seconds.
1940—		
January, 17.....	525 yards.....	6th badly bumped.
January, 24.....	525 yards.....	1st in 31·77 seconds.
January, 31.....	525 yards.....	6th in 32·16 seconds.
February, 8.....	525 yards.....	3rd in 31·81 seconds.
February, 14.....	525 yards.....	4th in 32·34 seconds.
February, 21.....	325 yards.....	2nd in 19·49 seconds.
February, 28.....	525 yards.....	2nd in 31·51 seconds.
March, 6.....	525 yards.....	5th in 31·71 seconds.
March, 13.....	325 yards.....	1st in 19·10 seconds.
March, 20.....	325 yards.....	5th in 19·60 seconds.
March, 27.....	525 yards.....	4th in 31·74 seconds.

TABLE 2.

The following are the racing performances of sterilised bitches running at Wembley Stadium:—

No. 1.—*Military Maid*; by Brigadier—Kilnafarna Lass, July, 1938. Operation 30/5/38.

1939—		
December, 13.....	325 yards.....	2nd in 19·72 seconds.
December, 20.....	325 yards.....	3rd in 19·57 seconds.
December, 27.....	325 yards.....	1st in 19·65 seconds.
1940—		
January, 3.....	325 yards.....	4th badly baulked.
January, 10.....	325 yards.....	1st in 19·07 seconds.
January, 17.....	325 yards.....	1st in 19·27 seconds.
January, 24.....	525 yards.....	4th in 31·99 seconds.
January, 31.....	525 yards.....	1st in 31·61 seconds.
February, 7.....	525 yards.....	3rd in 31·87 seconds.
February, 14.....	525 yards.....	2nd in 32·01 seconds.
February, 21.....	325 yards.....	3rd in 19·52 seconds.
February, 28.....	525 yards.....	1st in 31·33 seconds.
March, 6.....	525 yards.....	2nd in 31·36 seconds.
March, 13.....	525 yards.....	2nd in 31·36 seconds.
March, 20.....	525 yards.....	2nd in 31·90 seconds. rain.

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No. 2.—*Aandblom*; by Hell's Bells—*Ida's Lily*, March, 1938. Operation 21/11/38.

1939—		
August, 9.....	325 yards.....	6th in 19·91 seconds.
August, 10.....	325 yards.....	1st in 19·16 seconds.
August, 23.....	325 yards.....	1st in 19·03 seconds.
August, 30.....	325 yards.....	4th in 19·16 seconds.
September, 6.....	325 yards.....	4th in 19·11 seconds.
September, 13.....	325 yards.....	6th in 19·28 seconds.
September, 27.....	325 yards.....	2nd in 19·01 seconds.
September, 27.....	325 yards.....	2nd in 18·96 seconds.
October, 11.....	525 yards.....	2nd in 30·91 seconds.
October, 18.....	525 yards.....	3rd in 31·39 seconds.
October, 25.....	525 yards.....	4th in 31·06 seconds.
November, 1.....	525 yards.....	6th badly bumped.
November, 8.....	325 yards.....	3rd in 19·24 seconds.
November, 15.....	525 yards.....	3rd badly bumped.
November, 22.....	325 yards.....	4th in 19·32 seconds.
November, 29.....	325 yards.....	2nd in 19·13 seconds.
December, 6.....	325 yards.....	3rd in 19·13 seconds.
December, 13.....	525 yards.....	3rd in 31·27 seconds.
December, 20.....	525 yards.....	2nd in 31·53 seconds.
December, 27.....	525 yards.....	6th in 31·74 seconds.
1940—		
January, 3.....	525 yards.....	2nd in 31·42 seconds.
January, 10.....	525 yards.....	5th in 31·87 seconds.
January, 17.....	325 yards.....	6th in 19·63 seconds.
January, 24.....	325 yards.....	3rd in 19·61 seconds.
January, 31.....	325 yards.....	3rd in 19·45 seconds.
February, 7.....	325 yards.....	4th in 19·21 seconds.
February, 14.....	325 yards.....	3rd in 19·32 seconds.
February, 21.....	325 yards.....	5th in 19·67 seconds.
February, 28.....	325 yards.....	1st in 18·90 seconds.
March, 6.....	325 yards.....	2nd in 19·01 seconds.
March, 13.....	325 yards.....	6th in 20·06 seconds.
March, 20.....	325 yards.....	3rd in 19·21 seconds.

No. 3.—*Miss O'Grady*; by Comrade O'Grady—*Lady Jester*, March, 1938. Operation 3/11/38.

1939—		
August, 2.....	325 yards.....	5th in 19·62 seconds.
August, 16.....	325 yards.....	2nd in 19·40 seconds.
August, 30.....	325 yards.....	1st in 18·99 seconds.
September, 6.....	325 yards.....	4th in 19·15 seconds.
September, 13.....	325 yards.....	5th in 19·32 seconds.
September, 20.....	325 yards.....	3rd in 19·25 seconds.
October, 11.....	525 yards.....	5th in 31·37 seconds.
October, 18.....	525 yards.....	2nd in 31·43 seconds.
October, 25.....	525 yards.....	4th in 31·58 seconds.
November, 1.....	525 yards.....	5th badly impeded.
November, 8.....	325 yards.....	4th in 19·26 seconds.
November, 15.....	525 yards.....	5th badly bumped.
November, 29.....	325 yards.....	6th in 19·20 seconds.
December, 6.....	325 yards.....	1st in 18·77 seconds.
1940—		
February, 28.....	325 yards.....	6th in 19·45 seconds.
March, 6.....	325 yards.....	4th in 19·46 seconds.
March, 13.....	325 yards.....	6th in 19·53 seconds.
March, 20.....	325 yards.....	2nd in 19·14 seconds.
March, 27.....	325 yards.....	1st in 19·20 seconds.

No. 4.—*Lee Wind* ; by Pytchley—Battle Wind, September, 1938. Operation 22/8/39.

1940—		
March, 6.....	325 yards.....	5th in 19·99 seconds.
March, 13.....	325 yards.....	4th in 19·64 seconds.
March, 20.....	325 yards.....	3rd in 19·71 seconds.

No. 5.—*Black Magic* ; by Hell's Bells—Ida's Lily, May, 1938. Operation 8/11/38.

1939—		
August, 23.....	325 yards.....	5th in 20·48 seconds.
November, 22.....	325 yards.....	3rd in 20·10 seconds.
1940—		
January, 31.....	325 yards.....	6th in 19·99 seconds.
February, 7.....	325 yards.....	5th (knocked over).
March, 20.....	325 yards.....	2nd in 19·65 seconds.

No. 6.—*Lady Makebelieve* ; by Hell's Bells—Kilnafarna Lass, July, 1937. Operation 19/7/38.

1939—		
May, 17.....	325 yards.....	2nd in 19·33 seconds.
May, 24.....	325 yards.....	5th in 19·64 seconds.
1940—		
January, 3.....	525 yards.....	5th in 32·16 seconds.
January, 10.....	525 yards.....	3rd in 32·12 seconds.
January, 17.....	525 yards.....	2nd in 31·94 seconds.
January, 24.....	525 yards.....	3rd in 31·96 seconds.
January, 31.....	525 yards.....	3rd in 31·76 seconds.
February, 8.....	525 yards.....	2nd in 31·78 seconds.
February, 14.....	525 yards.....	5th in 32·28 seconds.

No. 7.—*Cookhouse Call* ; by Brigadier—Rolling Pin, August, 1938. Operation 5/7/39

1939—		
December, 13.....	325 yards.....	3rd in 19·78 seconds.
December, 20.....	325 yards.....	5th in 20·32 seconds.
December, 27.....	325 yards.....	4th in 19·75 seconds.
January, 3.....	325 yards.....	2nd in 19·85 seconds.
January, 10.....	325 yards.....	5th in 19·74 seconds.
January, 17.....	325 yards.....	3rd in 19·86 seconds.
January, 24.....	325 yards.....	3rd in 19·61 seconds.
January, 31.....	325 yards.....	3rd in 19·82 seconds.
February, 7.....	325 yards.....	1st in 19·69 seconds.
February, 14.....	525 yards.....	3rd in 32·22 seconds.
February, 21.....	525 yards.....	5th in 32·09 seconds.
February, 28.....	525 yards.....	3rd in 31·99 seconds.
March, 6.....	525 yards.....	5th in 32·07 seconds.
March, 13.....	325 yards.....	2nd in 19·16 seconds.
March, 20.....	325 yards.....	6th in 19·60 seconds.

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No. 8.—*Laughing Lass*; by Laughing Cavalier—Kilnafarna Lass, January, 1938.
Operation 8/11/38.

1938—		
November, 22.....	325 yards.....	4th in 20·18 seconds.
November, 29.....	325 yards.....	4th in 20·22 seconds.
December, 6.....	325 yards.....	1st in 19·65 seconds.
December, 13.....	325 yards.....	6th in 20·08 seconds.
December, 20.....	325 yards.....	5th in 19·80 seconds.
December, 27.....	325 yards.....	2nd in 19·54 seconds.
1940—		
January, 3.....	325 yards.....	5th (badly baulked).
January, 10.....	325 yards.....	4th in 19·62 seconds.
January, 17.....	325 yards.....	6th (badly baulked).
January, 24.....	325 yards.....	5th in 19·73 seconds.
January, 31.....	325 yards.....	2nd in 19·71 seconds.
February, 7.....	325 yards.....	2nd in 20·15 seconds.
February, 21.....	525 yards.....	6th in 32·21 seconds.
February, 28.....	525 yards.....	2nd in 31·93 seconds.
March, 6.....	525 yards.....	1st in 31·38 seconds.

No. 9.—*Army Beauty*; Brigadier—Kilnafarna Lass, July, 1938. Operation 2/5/39.

1938—		
December, 13.....	325 yards.....	4th in 19·81 seconds.
December, 20.....	325 yards.....	2nd in 19·42 seconds.
December, 27.....	325 yards.....	1st in 19·24 seconds.
1940—		
January, 3.....	325 yards.....	2nd in 19·09 seconds.
January, 17.....	325 yards.....	5th in 19·60 seconds.
January, 24.....	325 yards.....	1st in 19·22 seconds.
January, 31.....	525 yards.....	5th in 32·07 seconds.
February, 7.....	525 yards.....	1st in 31·77 seconds.
February, 14.....	525 yards.....	1st in 31·40 seconds.
February, 21.....	525 yards.....	1st in 31·20 seconds.
February, 28.....	325 yards.....	4th in 19·05 seconds.
March, 6.....	525 yards.....	6th (badly baulked).
March, 13.....	525 yards.....	2nd in 31·33 seconds.
March, 20.....	525 yards.....	4th (Baulked.)

No. 10.—*Charity's Aid*; by Moss Trooper—Mick the Damozelle. December, 1936.
Operation 21/5/37.

1938—		
July, 6.....	525 yards.....	3rd in 31·77 seconds.
July, 20.....	525 yards.....	6th (fell over).
August, 31.....	525 yards.....	5th in 32·49 seconds.
September, 7.....	525 yards.....	1st in 31·88 seconds.
September, 21.....	525 yards.....	5th in 32·39 seconds.
September, 28.....	525 yards.....	5th in 32·07 seconds.
October, 12.....	525 yards.....	5th in 32·89 seconds.
October, 19.....	525 yards.....	5th in 32·58 seconds.
November, 16.....	525 yards.....	5th in 32·17 seconds.
November, 23.....	525 yards.....	6th in 32·35 seconds.
December, 7.....	525 yards.....	5th in 32·32 seconds.
December, 14.....	525 yards.....	4th in 32·31 seconds.
December, 28.....	525 yards.....	4th in 32·91 seconds.

1939—

January, 4	525 yards	5th in 32·34 seconds.
January, 11	525 yards	4th in 32·08 seconds.
March, 22	325 yards	5th in 19·63 seconds.
April, 5	325 yards	4th in 19·45 seconds.
April, 12	325 yards	4th in 19·43 seconds.
April, 26	525 yards	4th in 32·14 seconds.
May, 3	325 yards	5th in 20·26 seconds.
May, 24	325 yards	3rd in 19·40 seconds.
June, 7	525 yards	5th in 32·19 seconds.
June, 14	325 yards	5th in 19·86 seconds.
June, 21	325 yards	1st in 19·13 seconds.
June 28	525 yards	1st in 31·41 seconds.
July 5	525 yards	6th in 31·90 seconds.
July 12	525 yards	2nd in 31·43 seconds.
July 19	525 yards	6th (badly baulked).
August 2	525 yards	5th in 32·20 seconds.
August 9	525 yards	5th in 31·97 seconds.
August 16	525 yards	5th in 32·07 seconds.
August 23	525 yards	3rd in 32·11 seconds.
August 30	525 yards	2nd in 31·59 seconds.
September 6	525 yards	3rd in 31·86 seconds.
September 13	525 yards	6th in 32·00 seconds.
September 20	525 yards	4th in 31·79 seconds.
September, 27	525 yards	4th in 32·08 seconds.
October, 4	525 yards	6th (badly bumped).
December 6	525 yards	4th in 32·74 seconds.

No. 11.—*Girl Friend*; by Brigadier—Lady Jester, December, 1936. Operation 21·5 37

1938 -

April, 6	525 yards	3rd in 31·92 seconds.
April, 13	525 yards	1st in 31·70 seconds.
April, 20	325 yards	3rd in 31·35 seconds.
April, 27	525 yards	4th in 31·42 seconds.
May, 4	525 yards	1st in 31·22 seconds.
May, 11	525 yards	5th in 31·61 seconds.
May, 18	525 yards	2nd in 31·22 seconds.
May, 25	525 yards	5th in 31·35 seconds.
June, 1	525 yards	1st in 31·11 seconds.
June, 8	525 yards	2nd in 30·92 seconds.
June, 15	525 yards	5th in 31·48 seconds.
June, 22	525 yards	6th in 31·37 seconds.
June, 29	525 yards	3rd in 31·22 seconds.
July, 6	525 yards	3rd in 31·47 seconds.
July, 13	525 yards	5th in 31·22 seconds.
July, 20	525 yards	4th in 31·49 seconds.
July, 27	525 yards	6th in 31·78 seconds.
August, 3	525 yards	1st in 30·87 seconds.
August, 10	525 yards	5th in 31·45 seconds.
August, 17	525 yards	5th in 32·01 seconds.
August, 24	525 yards	2nd in 31·41 seconds.
August, 31	525 yards	5th in 31·77 seconds.
September, 7	525 yards	3rd in 31·30 seconds.
September, 14	525 yards	4th in 31·38 seconds.
September, 21	525 yards	6th in 31·45 seconds.
December, 7	525 yards	3rd in 31·08 seconds.
December, 14	525 yards	6th in 31·43 seconds.
December, 21	525 yards	4th in 31·30 seconds.
December, 28	525 yards	3rd in 31·42 seconds.

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1939—

January, 4.....	525 yards.....	4th in 31·54 seconds.
January, 11.....	525 yards.....	2nd in 31·40 seconds.
January, 18.....	525 yards.....	3rd in 31·67 seconds.
January, 25.....	525 yards.....	6th in 31·66 seconds.
February, 22.....	525 yards.....	4th in 31·53 seconds.
March, 1.....	525 yards.....	5th (fell first bend).
March, 8.....	525 yards.....	2nd in 31·53 seconds.
March, 15.....	525 yards.....	2nd in 31·67 seconds.
March, 22.....	525 yards.....	5th in 31·86 seconds.
March, 29.....	525 yards.....	1st in 31·44 seconds.
April, 5.....	525 yards.....	3rd in 31·70 seconds.
April, 12.....	525 yards.....	2nd in 31·25 seconds.
April, 19.....	725 yards.....	4th in 44·17 seconds.
April, 26.....	525 yards.....	4th in 31·79 seconds.
May, 3.....	725 yards.....	6th in 44·33 seconds.
May, 10.....	725 yards.....	1st in 44·11 seconds.
May, 17.....	525 yards.....	2nd in 31·62 seconds.
May, 24.....	725 yards.....	4th in 43·96 seconds.
May, 31.....	525 yards.....	2nd in 31·47 seconds.
June, 7.....	525 yards.....	1st in 31·42 seconds.
June, 14.....	725 yards.....	6th in 44·72 seconds.
June, 28.....	525 yards.....	4th in 31·95 seconds.
July, 5.....	525 yards.....	5th in 31·90 seconds.
July, 12.....	525 yards.....	3rd in 31·28 seconds.
July, 19.....	525 yards.....	5th (badly bumped).
July, 26.....	525 yards.....	3rd in 31·47 seconds.
August, 2.....	525 yards.....	4th in 31·51 seconds.
August, 30.....	525 yards.....	1st in 31·67 seconds.
September, 6.....	525 yards.....	4th in 31·72 seconds.
September, 13.....	525 yards.....	5th in 32·42 seconds.
September, 20.....	725 yards.....	3rd in 44·49 seconds.
September, 27.....	525 yards.....	3rd in 32·56 seconds.
October, 4.....	725 yards.....	2nd in 44·71 seconds.
October, 11.....	525 yards.....	6th in 31·55 seconds.
October, 18.....	725 yards.....	1st in 44·71 seconds.
October, 25.....	725 yards.....	4th in 44·63 seconds.
November, 1.....	725 yards.....	6th injured.

No. 12.—*Suikerbossie*; by Hell's Bells—Last Queen, born September, 1937. Operation 23/6/38.

1938—

December, 28.....	525 yards.....	1st in 32·27 seconds.
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1939—

January, 4.....	525 yards.....	2nd in 31·90 seconds.
January, 11.....	525 yards.....	2nd in 31·74 seconds.
January, 18.....	525 yards.....	3rd in 31·76 seconds.
January, 25.....	525 yards.....	2nd in 32·41 seconds.
February, 8.....	525 yards.....	2nd in 31·38 seconds.
February, 22.....	525 yards.....	1st in 31·20 seconds.
March, 1.....	525 yards.....	3rd in 31·55 seconds.
March, 15.....	525 yards.....	4th in 31·89 seconds.
May, 17.....	525 yards.....	2nd in 31·46 seconds.
May, 24.....	525 yards.....	1st in 30·50 seconds.
May, 31.....	325 yards.....	1st in 18·98 seconds.
June, 7.....	375 yards.....	2nd in 19·04 seconds.
June, 14.....	325 yards.....	6th in 18·87 seconds.
June, 28.....	325 yards.....	5th (badly bumped).
July, 5.....	525 yards.....	2nd in 30·92 seconds.

1939 (continued)—		
October, 18.....	525 yards.....	3rd in 31·70 seconds.
October, 25.....	525 yards.....	3rd in 31·34 seconds.
November, 1.....	525 yards.....	3rd in 31·40 seconds.
November, 8.....	525 yards.....	1st in 31·17 seconds.
November, 15.....	525 yards.....	2nd in 31·00 seconds.
November, 22.....	525 yards.....	1st in 31·50 seconds.
November, 29.....	525 yards.....	3rd in 31·05 seconds.
December, 6.....	525 yards.....	2nd in 30·88 seconds.
December, 13.....	525 yards.....	5th in 31·30 seconds.
December, 20.....	525 yards.....	2nd in 31·07 seconds.
December, 27.....	525 yards.....	1st in 30·99 seconds.
1940---		
January, 3.....	525 yards.....	1st in 30·76 seconds.
January, 10.....	525 yards.....	3rd in 30·97 seconds.
January, 17.....	525 yards.....	2nd in 30·75 seconds.
January, 24.....	525 yards.....	2nd in 30·88 seconds.
January, 31.....	325 yards.....	6th in 19·41 seconds.
February, 7.....	525 yards.....	5th in 30·96 seconds.
February, 14.....	525 yards.....	2nd in 30·95 seconds.
February, 21.....	525 yards.....	1st in 30·63 seconds.
February, 28.....	525 yards.....	3rd in 30·74 seconds.
March, 6.....	525 yards.....	2nd in 30·80 seconds.
March, 13.....	525 yards.....	3rd in 30·88 seconds.
March, 20.....	525 yards.....	2nd in 30·96 seconds.

CONCLUSIONS.

1. Thirty-six greyhound bitches between the ages of six and 12 months have been oöphorectomised.
2. The oöphorectomised bitches have never shown the psychological or clinical symptoms of "heat".
3. Two oöphorectomised bitches have shown a tendency to slight increase in weight, 2-3 pounds, above that estimated as their best racing weights. Difficulty has been experienced in controlling the weight of these two bitches.
4. The performance of the oöphorectomised bitches has been comparable with that of their litter sisters.
5. Oöphorectomy appears to be a practical method of overcoming the difficulty experienced with greyhound bitches necessitating enforced rest from racing following each "heat" period.
6. Greyhound stud owners should consider the advisability of oöphorectomising all females not destined for stud purposes.

Section V.

Pathology.

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A Method for Preparing Sections of Bone Without Decalcification.

By A. D. THOMAS, R. CLARK, and K. SCHULZ,
Section of Pathology, Onderstepoort.

It is usual in histological technique to soften bone by subjecting it to some form of decalcification prior to embedding and cutting. The resulting preparation, while suitable for most histological purposes, offers some disadvantages when the degree of ossification or calcification, as well as the structure and growth of bone, have to be studied in relation to each other.

Depending on the method employed, the loss of mineral salts by such decalcification can be quite considerable as is apparent from the few figures, below, and it is also more than probable that the prolonged treatment with acids does not tend to improve the staining properties of the cells. This loss of salts was shown in a small experiment in which transverse rings, about 3 mm. thick, were sawn from the compact shaft of a metacarpus of a horse. The pieces were weighed the first time in the dry state (i.e. fat and water free) and then subjected to the most common methods of "softening", the material being deemed soft when a needle could be pushed through the thickness of the ring with ease.

Medium.	Length of time treated.	Loss of weight dry.
Nitric acid 5 per cent.....	3 days (soft).....	79 per cent. loss.
Formic acid and Sod. citrate.....	18 days (soft).....	73 per cent. loss.
Müller's fluid.....	3 months (still hard)..	25 per cent. loss.
Celloidin cedar wood oil.....	3 months (hard).....	5 per cent. gain in weight.

The gain in the latter case was evidently due to the celloidin with which the bone had become impregnated, as no attempts were made to dissolve and wash this out before drying and weighing the pieces of bone the second time.

It will be appreciated, therefore, that in deficiency disease such as osteoporosis, rickets, etc. and even in normal histology of growing bone, where the degree and mode of calcification is such a variable quantity, the ability to study and compare bone in sufficiently thin but uniform sections, without any previous interference with the calcification process, is of considerable importance.

The possibilities and disadvantages of preparing section from non-decalcified bone were mentioned in an earlier publication (Thomas and v. d. Wath, 1937) using the freezing microtome.

Fairly good sections may be obtained in this way, especially if the material is from a young animal or soft from the effects of advanced disease. When the bone is harder, the delicate lamellae tend to crumble before the knife, even when support is given in the form of a preliminary embedding in gelatine. The more brittle the material, therefore, the greater is the thickness at which it has to be cut. It is this uneven thickness of sections which makes comparison of the process so difficult and which has led to endeavours being made to find means of embedding and cutting bone, which would give more uniform and satisfactory sections.

The embedding method outlined below was evolved largely thanks to the untiring efforts of our technical assistant, Miss Moolman, to whom the greatest credit is due. The method certainly does not solve all the difficulties, nor does it allow of the cutting of the harder types of bone such as the compact substance of the shaft of a long bone. However, with care and some dexterity, excellent section can be obtained of the softer and moderately hard bones, especially the costo-chondral junctions of the ribs. Such sections can be cut to a uniform thickness 5-10 μ and stained by most of the more useful methods, Von Kossa's silver impregnation, Haemalum-eosin, Von Gieson, etc. Strange as it may seem, good sharp microtome knives do not seem to suffer any damage when cutting even fairly hard bone embedded in this way, provided care is taken in handling the microtome. The process is essentially a double embedding method (celloidin-paraffin) for which nothing original is claimed except its adaptation to the cutting of non-decalcified bone.

Briefly it consists of the following operations:—

Selected pieces of fresh bone are sawn into small slices about 3 mm. thick or less so as to include a portion of the cartilaginous line of growth. Biopsy material e.g. the costo-chondral junction of ribs including a few mm. of the cartilage may be divided into slices with a sharp knife with the piece of rib lying on its flat surface. Such pieces are fixed in formalin for a day or more and are then ready for the embedding process which comprises the following steps:—

- I. Wash in running water for 1-2 hours to remove all traces of formalin as this adversely affects the silver nitrate staining.
- II. Dehydrate in 70, 80, 90, and 100 per cent. alcohol in two days changing overday and overnight.
- III. Ether-alcohol aa one day.
- IV. Celloidin 2 per cent. one or two days.
- V. Celloidin 4 per cent. one or two days.
- VI. Wipe off excess celloidin and place piece in small quantity of chloroform.

- VII. When material sinks in chloroform, about an equal amount of cedar wood oil is added gradually during the day, the vessel being left open for the chloroform to evaporate and left therein overnight.
- VIII. Change to fresh cedar wood oil and leave for 2-3 days or indefinitely until ready to embed.
- IX. Place in benzine bath in oven at 58° C. for 10-15 minutes to remove excess cedar wood oil only.
- X. Embed and fix firmly to microtome block. (Wax of M.P. 50° C. is used here, but higher M.P. may be found more suitable elsewhere.) Cut in the usual way on sliding knife type microtome with a fairly heavy knife set at a good slant. Cooling of the embedded piece with ice prior to cutting is essential with this low M.P. wax. Normal porcine and bovine rib material is usually easier to cut than ovine and caprine which is harder. Sections from 5-10 μ thick for small pieces and up to 15 μ for larger ones can be obtained in this way. It must be stressed, however, that a person attempting this for the first time must be prepared to spend a considerable amount of patience and time until the knack of handling this hard material is acquired.

Once cut the sections are fixed to the slide with glycerin-albumen, allowed to dry in an oven at 37° C. for 2-3 days, deparaffinated, and stained in the usual way. For storage the pieces should preferably be returned to cedar wood oil, or failing this be re-embedded in paraffin to prevent the drying out of the cedarwood oil, as this renders the material difficult or impossible to cut.

It will be seen thus, that impregnation with cedar wood oil undoubtedly has an indirect "softening" effect, which, however, is insufficient for cutting the more compact types of bone. This effect can possibly be explained as a "lubrication" of the path of the knife in its passage through the calcareous matrix. This together with good support afforded by the double embedding can be said to constitute the essentials of this method.

REFERENCE.

- THOMAS, A. D., AND VAN DER WATH, J. G. (1937). Bone Biopsy as an Aid to the Study and Diagnosis of Deficiency Diseases. *Onderstepoort Jnl. of Vet. Sci., and An. Ind.*, Vol. 8, No. 2. pp. 431-439.

Experimental Osteodystrophic Diseases in Goats.

By J. W. GROENEWALD, Section of Biochemistry; A. D. THOMAS, Section of Pathology; and B. A. DU TOIT, Section of Biochemistry, Onderstepoort.

THE late Sir Arnold Theiler started an elaborate programme of work with the object of studying bone diseases in various species of common farm animals. These experiments have contributed markedly to the elucidation of the complicated problem of osteodystrophic diseases, their aetiology and histological differentiation. Phases of this project dealing with cattle, pigs and horses have been published by Theiler A., du Toit, P. J., and Malan, A., I., in two studies (1937) and by Groenewald (1937). As these publications deal fully with the relevant literature, their review here is considered superfluous. Although the histological bone pictures show distinct differences between rickets on the one hand and osteofibrosis or osteodystrophia fibrosa on the other, clinical symptoms vary in the different species.

Marek (1931) gives illustrations of ostitis fibrosa in the goat, from which it may be seen that the facial swellings are higher than in the horse, stretching up to the lachrymal, and malar bones. Wester (1935) writes that spontaneous rickets occurs in goats in Holland and that such goats are stiff, stunted in growth and frequently walk on their knees. It is conceivable that the domesticated milk-goat type of Europe would be more likely to suffer from some bone disease or other, if adequate rations are not given, than the unproductive goats which are accustomed to fend for themselves on the veld in this country.

Experimental work recently carried out by Glock *et al* (1939) showed that osteofibrosis was produced in goats fed for a relatively short period on a ration consisting of flaked maize and bran, with a minimum amount of hay. Not only was the blood serum calcium low, but actual swellings of the jaws, lameness, and paresis occurred. These authors are of the opinion that the higher vitamin D present under South African conditions may have contributed to the fact that the investigators in the latter country were unable to show that the blood calcium could be affected by a low intake of calcium. An abundance of vitamin D was present in the case of all the work done in South Africa.

EXPERIMENTAL.

Eight six-months old goats were selected for this work. Unfortunately the available animals varied considerably in regard to type, but this objection is less serious in view of the fact that the main criterion was to be the clinical symptoms and bone pathology, instead of body weight and size.

Four groups of two animals each were treated as follows:—

<i>Basal Ration.</i>	<i>Composition (gm.).</i>		
	P_2O_5	CaO	Protein.
50 gm. Hay	0.10	0.20	3.0
300 gm. Samp	0.27	0.05	30.0
50 gm. Blood meal	0.20	0.08	35.0
100 gm. Green feed	0.10	0.10	2.0
TOTAL (gm.)	0.67	0.43	70.0

In addition to the basal ration which was fed in boxes placed in individual pens, the mineral supplements were administered orally to each animal, once daily. The total calcium and phosphorous intake per animal, as well as the $CaO:P_2O_5$ ratio was:

Group.	CaO Intake.	P_2O_5 Intake.	$CaO:P_2O_5$.
4	3.95 gms.	3.73 gms.	1.06:1.0
1	0.43 gms.	4.73 gms.	1:11
2	9.92 gms.	0.67 gms.	14.8:1
3	0.43 gms.	0.67 gms.	1:1.6

The supplements were given in the form of calcium carbonate ($CaCO_3$), and di-sodium phosphate (Na_2HPO_4). It will, therefore, be seen that the object was to create extreme conditions of: low calcium—high phosphorus; high calcium—low phosphorus; low calcium—low phosphorus, but in a normal ratio; and sufficient calcium—sufficient phosphorus in a normal $CaO : P_2O_5$ ratio.

The kids were run in a small cement-floored paddock during the day. In spite of this floor the animals had to be muzzled, as they made attempts at every opportunity to get hold of manure or to lick the floor. During the night they stayed in their individual pens, also on cement floors, but provided with sleeping boards. Food consumption was poor and unsatisfactory in all cases. At every opportunity the animals persisted in lying in the feed boxes with the result that these, as well as the feed, were fouled with faeces and urine. On this account weighing back of the unconsumed feed, although done regularly, was unreliable from the point of view of exact calculation. However, it may definitely be stated that food consumption was far more satisfactory in the case of group 4 (control) than in the other groups.

All the animals were bled monthly for the determination of blood calcium and inorganic phosphorus. Monthly live weights were recorded and rib-resections were made periodically for histopathological studies. Internal parasites were carefully controlled, as well as the general health of the animals attended to.

RESULTS.

The clinical progress very briefly given for each group is as follows:—

$$\text{GROUP 1.} \quad : \quad \frac{\text{CaO}}{0.43 \text{ gms.}} \quad : \quad \frac{\text{P}_2\text{O}_5}{4.73 \text{ gms.}} \quad = \quad 1 : 11.$$

Date.	Goat 41661.	Goat 40922.
20/ 5/35	Experimental ration started.....	Experimental ration started.
6/ 7/35	Diarrhoea, which occurred at frequent intervals throughout the experiment	Diarrhoea, which occurred at frequent intervals throughout the experiment
18/12/35	—	Developed peculiar gurgle in its throat.
3/ 4/36	—	Rib section taken—bone normal.
7/ 8/36	—	Slight swelling on right side of face.
20/ 8/36	—	Rib section, very slight red seams, slight fibrosis.
20/10/36	—	Rib section—slight fibrosis.
2/ 6/37	Rib section—slight fibrosis.....	—
28/ 4/37	—	Very weak and stunted appearance.
4/ 5/37	—	Died—Marked atrophy or osteoporosis. No osteofibrosis.
15/ 2/38	Died—Marked atrophy or osteoporosis. No osteofibrosis	—

$$\text{GROUP 2.} \quad : \quad \frac{\text{CaO}}{9.92 \text{ gms.}} \quad : \quad \frac{\text{P}_2\text{O}_5}{0.67 \text{ gms.}} \quad = \quad 14.8 : 1.$$

Date.	Goat 41594.	Goat 41906.
20/ 5/35	Experimental ration started.....	Experimental ration started.
11/ 7/35	Constipated.....	—
3/4/36	Rib resected—rickets.....	Weak and lies down a lot.
23/ 4/36	—	Too weak to walk far.
11/ 6/36	—	Accidentally killed by an ox.—Slight rickets.
26/ 6/36	Developed bad "cowhocks".....	—
20/ 7/36	Hind legs badly bent.....	—
27/ 8/36	Given mineral supplement.....	—
23/ 9/36	Improved considerably.....	—
23/11/36	Died—Abscess in lung; bone atrophy	—

OSTEODYSTROPHIC DISEASES IN GOATS.

$$\text{GROUP 3.} \quad : \quad \frac{\text{CaO}}{0.43 \text{ gms.}} \quad : \quad \frac{\text{P}_2\text{O}_5}{0.67 \text{ gms.}} \quad = \quad 1 : 1.6.$$

Date.	Goat 41459.	Goat 41902.
20/ 5/35	Experimental rations started.....	Experimental rations started.
1/ 9/35	Lame in front leg.....	—
24/ 2/36	—	Weak on its legs.
9/ 4/36	—	Rib resection—Marked rickets.....
20/ 8/36	Rib resected—Slight rickets.....	—
25/ 8/36	Lame in right hind leg, joints, painful	—
20/10/36	Rib resected—Slight rickets.....	—
3/ 6/37	Rib resected—Normal, but slight osteoid seams	—
7/ 2/38	Died—Slight atrophy.....	—

$$\text{GROUP 4.} \quad : \quad \frac{\text{CaO}}{3.95 \text{ gms.}} \quad : \quad \frac{\text{P}_2\text{O}_5}{3.73 \text{ gms.}} \quad = \quad 1.06 : 1.$$

Date.	Goat 41915.	Goat 44323.
20/ 5/35	Experimental ration started.....	Experimental ration started.
16/ 9/35	—	Gave birth to a kid which was very weak and small.
27/ 1/36	—	Kid destroyed in order to give the mother a better chance.
2/11/36	—	Died sequel to pulmonary haemorrhage; bone normal.
3/ 6/37	Rib resected—Normal.....	—
16/ 3/38	Destroyed—Bone normal.....	—

The clinical record of the goats indicates that marked symptoms of osteofibrosis were not seen. Rickets made its appearance and was especially marked in No. 41594, Group 2. Both goats in Group 3, Nos. 41459 and 41902 became weak and were inclined to show lameness which became aggravated at times.

Interesting facts were revealed from the rib section and autopsy studies.

Group 1. Low Calcium: High Phosphorus.—About 15 months after the commencement of the experiment a diagnosis of slight osteofibrosis was made. However, a year later marked atrophy or osteoporosis was recorded in the case of both animals in this group. This fact is consistent with the relatively poor food consumption of these goats, and the occurrence of intermittent diarrhoea.

Group 2. High Calcium: Low Phosphorus.—The histological diagnosis of advanced rickets was made on No. 41594, eleven months after this goat had been placed on the experimental ration. An autopsy on this animal's group mate No. 41906, two months later showed that rickets, although present, was less marked. When No. 41594 was considered to be practically in *extremis*, the mineral

supplements of Group 4 (control) was administered. Although the animal improved clinically, feed consumption remained poor and death eventually occurred as a sequel to lung abscesses. At this stage, 6 months after a diagnosis of rickets had been established histologically, the bone picture left no doubt as to the presence of atrophy.

Group 3. Low Calcium: Low Phosphorus.—Histological examination of the rib, in the case of No. 41902, showed that marked rickets was present eleven months after the commencement of the experiment. Four months later the group mate No. 41459 showed only slight rickets. When the latter animal was autopsied, ten months later, osteoporosis was diagnosed.

Group 4. Sufficient Calcium: Sufficient Phosphorus.—Notwithstanding the fact that one of these young animals accidentally became pregnant and gave birth to a normal kid, histological examination of the bone showed that it remained normal. The group mate of this animal outlived all the other animals in the experiment and was found to have a normal healthy bone at the conclusion of the work.

The general appearance and condition of the animals was recorded in a photograph taken after they had been on the experimental ration for 15 months. Unfortunately three goats had already been lost by this time.



Fig. 1.

The animals numbering from left to right are: Group 1, Nos. 41661 and 40922; Group 2, No. 41494; Group 3, No. 41459; and Group 4, No. 41915.

From the appearance of the animals shown in Fig. 1 it is apparent that they were of mixed origin. As shown No. 41661 (Group 1) is a much bigger and stronger animal than its group mate No. 40922. The control animal No. 41915 is shown to be in good condition and to have a good glossy coat.

The average group weights in pounds are given in Fig. 2.

It will be seen from the monthly weights that very satisfactory gains were recorded in the case of Group 4 (control). Although the average weight gains for the other groups were poor, Group 1 (calcium low) appeared to be the best, but this may be attributed largely to the fact that No. 41661, as already shown was a stronger animal. The poorest group, in so far as a depression of average monthly weights was concerned, was undoubtedly Group 2 (phosphorus low). The sudden upward trend of the curve was due to the death of the weakest kid.

The monthly average group blood calcium figures are given in Fig. 3.

From these curves it will be seen that there were no marked group differences in the average blood calcium figures. However, Group 2 (high calcium: low phosphorus), did show a high blood calcium figure which gradually declined and was normal by the eighth month of the experiment.

The curves illustrating the average monthly inorganic blood phosphorus are given in Fig. 4.

This figure shows that the inorganic blood phosphorus was definitely high in the case of Group 1 (low calcium—high phosphorus). The average blood phosphorus, although relatively low during the first half of the experimental period in Group 3 (low calcium—low phosphorus), showed an improvement during the latter half of the period.

DISCUSSION.

A survey of the results obtained once again demonstrates the advantage of bone biopsy as an aid to the study and diagnosis of deficiency diseases. For instance, an unfavourable factor such as poor and irregular food consumption would have rendered the work practically useless if weight gains and clinical symptoms alone had been the criterion of changes produced. However, since histological studies were carried out periodically on the bone sections, the progressive development of the osteodystrophic conditions could be followed and a better understanding of bone ossification obtained. For instance, a careful perusal of the results in the case of the two animals which received an intake of 0.43 grams CaO and 4.73 grams P_2O_5 daily, and where the CaO: P_2O_5 ratio was 1:11, shows that both these animals had developed slight osteofibrosis in about 18 months to two years after the commencement of the experiment. However, it would seem that these animals adapted themselves to a new low level of metabolism and mineral conservation, since the autopsy done approximately a year later showed that instead of the osteofibrosis progressing as could be expected, a marked atrophy of the bone became evident. A tendency to calcium conservation may thus explain why the development of osteofibrosis may be retarded or even prevented. In this case an over-abundance of phosphorus did not prevent bone atrophy when once a total deficiency of nutrients occurred. As direct sunlight and green feed were

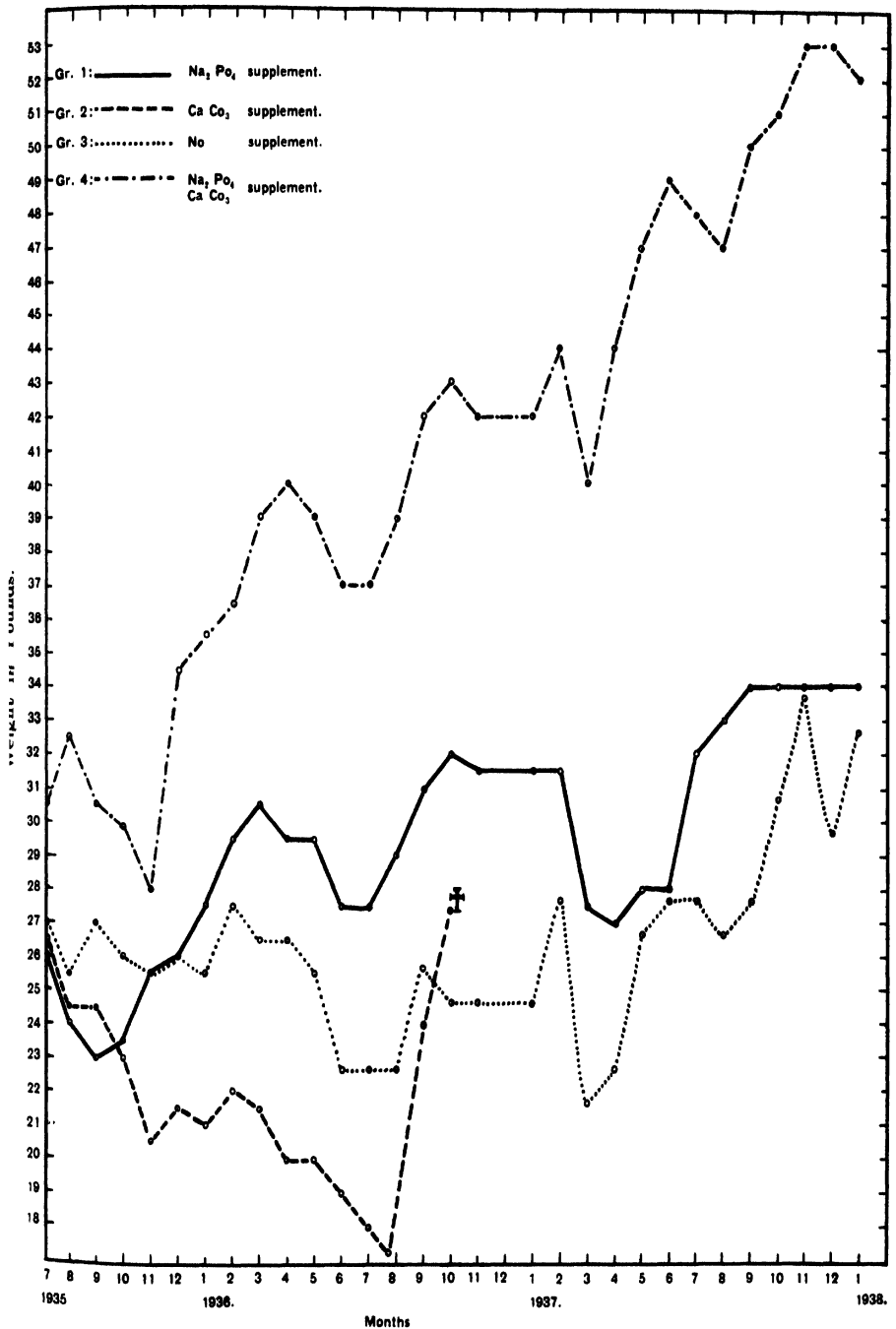


Fig. 2.—Monthly Group Weights.

Fig. 3. Blood Calcium.

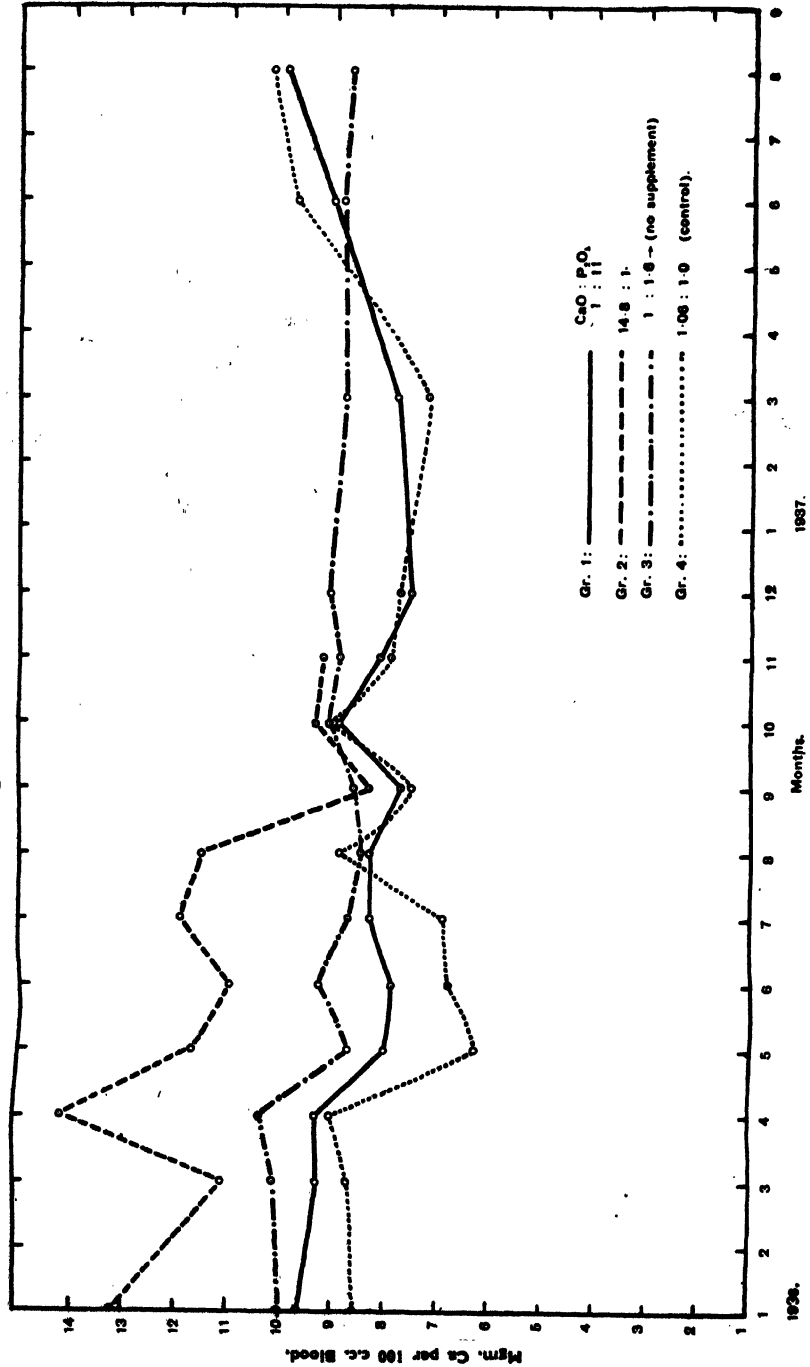
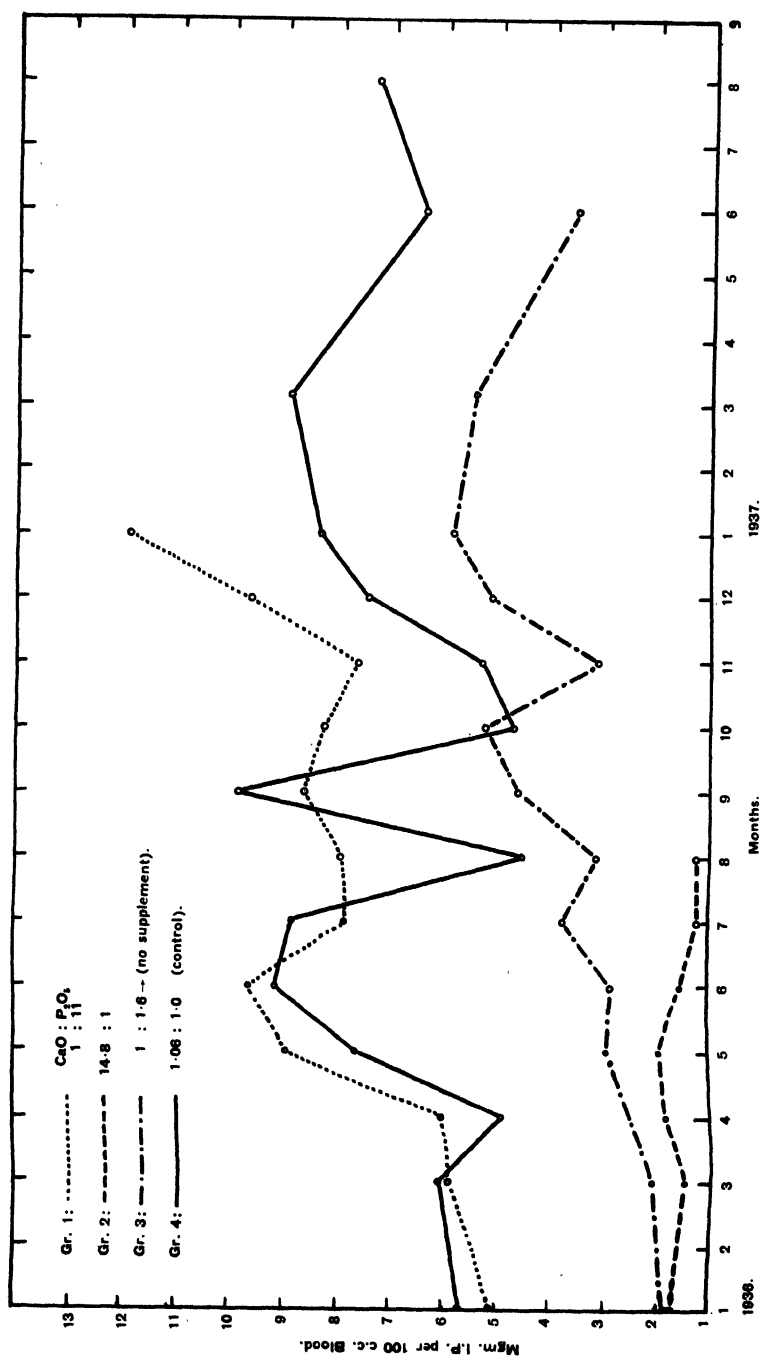


Fig. 4.—Inorganic Blood Phosphorus.



available at all times, it may be accepted that there was no lack of vitamins A and D. The inorganic blood phosphorus (Fig. 4), shows that this element was present in an abnormally high blood concentration and supports the contention that other factors, e.g. a protein deficiency must have prevented its proper utilization.

The low food intake was accompanied by a disinclination of the goats to walk and a general inactivity. The stunted appearance of these animals (Fig. 1) indicates that growth was severely retarded. Some or all these factors possibly exercised an inhibitory influence on the development of osteofibrosis.

A consideration of the results obtained in Group 2, where the calcium intake was 9.92 gms. and the phosphorus 0.67 gms. daily, with a calcium:phosphorus ratio of 14.8:1, shows that eleven months after the commencement of the experiment advanced rickets was recorded in one animal. The group mate had slight rickets when accidentally killed a month later. Eight months after diagnosing rickets in the former case, this animal actually showed severe clinical rickets. At this stage the mineral supplement was changed to that of the control group. The animal showed a considerable degree of clinical improvement, but upon death three months later, a diagnosis of bone atrophy was made.

The weight curve (Fig. 2) shows that the low phosphorus intake resulted in a marked weight depression. Similarly the inorganic blood phosphorus never reached the level of 2 mgm. per 100 c.c. blood. The calcium appeared to be relatively high, but gradually sank until it reached the normal level of approximately 9 mgm. per 100 c.c. blood in eight months' time.

Although the food consumption of these animals was as poor as that of the kids on the low calcium intake, marked rickets became manifest in the former in a shorter period than did osteofibrosis in the latter. Substantiating evidence of the early development of conditions favourable to rickets may be seen in the body weights of this group.

When the calcium intake was 0.43 grams and the phosphorus 0.67 grams daily, with a $\text{CaO}:\text{P}_2\text{O}_5$ ratio of 1:1.6, as shown in Group 3, very marked rickets was established in one kid at the end of the first year. The group mate of this animal only showed slight rickets six months later. At the conclusion of the experiment a diagnosis of slight atrophy was made in the latter case. With the exception of a comparatively low inorganic blood phosphorus figure, shown in Fig. 3, no definite conclusion can be drawn from the other observations in this group.

Theoretically, when the calcium and phosphorus intakes are so low that no growth takes place, through voluntary starvation or inadequacy of these elements in the diet, one would expect nothing worse than bone atrophy to develop. In practice, however, such low intakes of calcium and phosphorus are not easily affected, and as in the present experiment rickets, which is relatively easily produced on a phosphorus deficient diet, develops. Although bone biopsy established florid rickets in one of the animals that received

both calcium and phosphorus low intakes in conjunction with a favourable ratio, definite clinical rickets was recognized only in one case where the calcium intake was high and the $\text{CaO}:\text{P}_2\text{O}_5$ ratio consequently wide.

The control group, the animals in which received 3.95 grams of CaO and 3.73 grams of P_2O_5 each daily, and where the $\text{CaO}:\text{P}_2\text{O}_5$ ratio was 1.06:1.0, remained in good condition as shown by the steady increase in weight (Fig. 2). Examinations of all bone sections showed that both animals in this group remained normal.

CONCLUSIONS.

(1) Starvation proved to be an important factor in the development of bone atrophy in the case of two kids which received a ration low in calcium and high in phosphorus, where the $\text{CaO}:\text{P}_2\text{O}_5$ ratio was wide.

(2) Clinical symptoms of rickets were observed only in a case where the phosphorus intake was low and that of calcium high, with a wide ratio.

(3) When the calcium and phosphorus intakes were both low, their ratio being normal, the histological examination of the bone showed the presence of rickets.

(4) The inhibition of normal growth, due to semi-starvation, resulted in the eventual development of bone atrophy and not osteofibrosis. Even rickets, which is more easily produced than osteofibrosis, in time gives way to atrophy in the presence of cessation of bone growth.

ACKNOWLEDGMENTS.

The authors wish to record their appreciation to Dr. A. I. Malan for his assistance in planning and the interest he took in this work.

REFERENCES.

- GLOCK, G. E. AND MURRAY, M. M. (1936). Preliminary observations on the effects of a low calcium diet on goats and kids. *Jour. of Com. Path. and Ther.*, Vol. 52, pt. 3, pp. 229-248.
- GROENEWALD, J. W. (1927). Osteofibrosis in equines. *Onderstepoort Jour. of Vet. Sc. and An. Ind.*, Vol. 9, No. 2, pp. 601-620.
- MAREK, J. AND WELLMAN, O. (1931). Die Rhachitis. *Pathologischen Teil. Jena, Gustav Fischer*, pp. 51-64.
- THEILER, A., DU TOIT, P. J. AND MALAN, A. I. (1937). Studies in the mineral metabolism XXXVIII. The influence of variations in the dietary phosphorus and in the $\text{Ca}:\text{P}$ ratio on the production of rickets in cattle. *Onderstepoort Jour. of Vet. Sc. and An. Ind.* Vol. 8, No. 2 pp. 375-414.
- THEILER, A., DU TOIT, P. J. AND MALAN, A. I. (1937). Studies in mineral metabolism XXXVIII. Calcium and phosphorus in the nutrition of growing pigs. *Onderstepoort Jour. of Vet. Sc. and An. Ind.* Vol. 9, No. 1, pp. 127-164.
- WESTER, J. (1935). *Orgaanziekten by de groot huisdieren*. Drukkery J. van Boekhoven, Utrecht en Amsterdam, bl. 630.

Section VI.

Wool Research.

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Studies on the Basic Characteristics of South African Merino Wool.—I. Breaking Strength and Tensile Strength.

By V. BOSMAN, ELEANOR A. WATERSTON and C. M. VAN WYK, Wool Research Section, Onderstepoort.

THE basic characteristics of the raw material from which textiles are manufactured largely determine the characteristics of the finished cloth, and a knowledge of the basic characteristics of the raw material is valuable.

It has already been shown (Bosman, 1937) that the Union of South Africa produces an extremely fine fibred type of Merino wool which is used as raw material in the manufacture of fine fibred fabrics.

As regards the other characteristics, little experimental data have been available and information regarding South African wool could not be given to the users of the raw product. In addition, the wool producer has not been able to compare his product with other textile fibres, nor has he known how to effect improvements in his raw material.

Other textile organisations, such as those that control the manufacture of synthetic fibres, are in a stronger position in this respect, since by constant research they are able to say precisely what the intrinsic characteristics of their products are. In their case the continued improvement in the characteristics of synthetic fibres is due to intensive researches.

This position was realised by the South African Wool Council and research projects for studying the basic characteristics of South African Merino wool were financed by the Council out of Wool Levy funds.

The present contribution deals with tensile strength. Other characteristics are described elsewhere.

Apart from the actual experimental results presented in these publications, a great deal of work has had to be undertaken to evolve suitable methods for expressing the characteristics in arithmetic and

comparable terms. This system is also essential in research work that deals with Merino wool from production aspects and it forms the basis for further work on researches into Merino genetics and nutrition.

REVIEW OF LITERATURE.

Although several publications, dealing with the breaking strength and tensile strength of wool from different breeds of sheep are available, no work dealing directly with the breaking strength and tensile strength of South African Merino wool is known.

The first reliable estimate of the breaking load of wool appears to be recorded by McMurtrie (1886) who gave average values for various breeds of sheep. Matthews (1904) designed an instrument for determining breaking strength and considered that an average of 10 fibres per sample gave a reliable estimate of the characteristic. Hill (1908, 1911, 1912) concluded that an average obtained from a 1,000 fibres per sample was not reliable and considered that the breaking strength is more nearly proportional to the diameter of the fibre than to the square of the diameter.

Miller and Tallman (1915) studied the tensile strength of wool fibres, testing 1,000 fibres per sample. Gldenpfennig (1915) studied the breaking strength of fibres from pure-bred and cross-bred sheep. Hardy (1918, 1920) concluded that the tensile strength of wool, both in the grease and as scoured, decreased with an increase in relative humidity from 40 per cent. to 80 per cent. and showed a tendency to increase thereafter to saturation. Hardy stressed the need for diameter measurements and considered that the smallest diameter should be used in calculating tensile strength. He found an increase in the tensile strength with a decrease in fibre diameter and asserted that the breaking strength of fine wool varied more closely with the first than with the second power of the diameter, while the breaking strength of coarse wool varied with a figure lying somewhere between the first and second powers of the diameter.

Kronacher (1924) found a high correlation between fineness and breaking strength and gave standards of breaking strength for the various fineness classes.

Khler (1924) found a higher tensile strength for fine than for coarse wools in the case of Karakul sheep, his conclusions being verified by Dimitriadis (1926) who used wool from Merino yearlings. Deppe (1926) found a high correlation between fineness and breaking strength. Further investigations were carried out by Tnzer (1926) and Anert (1929), the latter using the smallest fineness value for the calculation of tensile strength. Kraus (1927), whilst reviewing the testing methods used at Dresden, gave instances of the value of tensile strength determinations.

Ogrizek (1926) and Constantinescu and Contescu (1928) found correlations between breaking strength and diameter in a study of the wool of Zigaja sheep.

Barker and Hedges (1927) found a decrease of approximately 0.57 per cent. in the breaking strength of yarns for each 1 per cent. rise in relative humidity. Reimers and Swart (1930) studied the relation between diameter, extensibility and carrying capacity of fibres from a number of closely related Merino rams. Saur (1931) advocated the standardisation of the duration of the time of tests on tensile strength.

The variation of tensile strength and extensibility and their correlation with fibre fineness were studied by Kärner (1932). Doehner (1932) devised an apparatus for determining the tensile strength of a bundle of fibres, and later (1935) applied the instrument in a study of the monthly and yearly variations of tensile strength in the wool of sheep of the most important breeds occurring in Germany.

Cunliffe (1933) published photographs of fibres under stress which showed clearly the diminution of fibre diameter during stretching. Schmidhäuser (1936) compared the tensile strength, extensibility and fineness of various textile fibres including staple fibre.

An extensive series of experiments on the elastic properties of wool was commenced by Speakman (1924, 1926, 1927, 1928, 1929, 1930 and 1931) using English Cotswold wool. He was able to form a picture of the structure of the fibre and explain its properties. The work was supplemented by X-ray studies (Ewles and Speakman 1928 and 1930).

EXPERIMENTAL.

The Selection of Samples and Methods of Analysis.

The South African wool clip is produced under varying conditions of climate and pasturage and a representative selection of the clip must take into account the types of wool produced in the different wool-growing areas.

The question of how a representative selection of samples from the South African Merino clip could be obtained was carefully considered. Assuming that there are approximately 50,000 Union farmers who sell wool, the question of obtaining samples from each of these clips would make a study of this nature prohibitive. A reasonable representative selection of samples could be obtained, however, by choosing representative samples from distinctive wool growing areas. The range of samples used for the study therefore includes types grown on grass-veld, mixed-veld and karroo-veld and were obtained from wool growing areas of the four provinces of the Union.

The laboratory determinations of the series of samples were carried out on a representative selection of fibres taken from a larger lot of wool, whether this was a farmer's clip, a bale or a lesser quantity. Each case was treated on its own merits and a sample taken according to the size of the lot.

The instrument used for the test was that devised by Doehner (1932). It was found to be very suitable for these studies, since it determines the mean breaking strength of a bundle of fibres and for this reason was preferred to other existing instruments.

Usually the original sample was divided into zones, fifteen to thirty, or more, depending on the size of the sample, and single staples were drawn at random from each zone in succession, until a sub-sample of about 100 grams had been made up. From each of the staples forming a sub-sample, a small strand of fibres was separated off and cleansed in ether, the strands being laid side by side after washing. A single fibre was drawn at random from each strand and after being straightened just sufficiently to eliminate the crimping, was mounted on a frame devised by Doehner (1932) and its ends secured with adhesive wax. When a hundred fibres had been mounted, the ends of the bundle were fixed by sealing wax to a strip of paper perforated by a special instrument that is included in the Doehner apparatus. The mean value obtained from three such bundles made up of fibres from the original sub-sample, was shown, by special tests, to be of sufficient accuracy for the purpose of the present study. It was shown that the variation among the three bundles of a sample (expressed by a standard deviation of ± 0.080) was considerably smaller than the variation among the different samples (the standard deviation of the latter being ± 0.231). There was thus a real difference in the tensile strengths of different samples.

All determinations were carried out in a room maintained at a constant relative humidity of 70 per cent. at a temperature of 70° Fahrenheit. (According to tests made on a number of samples, values obtained at 70 per cent. relative humidity may be adjusted to correspond to 65 per cent. relative humidity by adding 0.45 (± 0.21) grams to the breaking strength, and $0.14(\pm 0.04) \times 10^6$ gms./cm.² to the tensile strength). The paper strips containing the fibres were placed in a desiccator for 24 hours before being exposed to the conditions of the humidity chamber. The fibres therefore in all cases contained moisture corresponding with adsorption conditions.

The breaking strength was determined at points two millimeters apart on the bundle of fibres, this operation being aided by the perforations on the paper holding the bundles. The number of points of breaking was thus dependent on the length of the bundle of fibres and usually ranged from 3 to 5.

The rate of loading of the instrument was 2 kilogrammes per minute giving an average of 20 grammes per minute for individual fibres. The load at break was read off directly on the calibrated scale.

When the tests were made, the Onderstepoort Wool Research Laboratories had, for certain reasons, its Constant Humidity Chamber set at 70 per cent. Relative Humidity and 70° Fahrenheit. Since then the conditions have been changed to the internationally adopted standard of 65 per cent. Relative Humidity and 70° Fahrenheit.

After the fibres forming one bundle, had been broken, all the fragments were collected and mounted on a slide in Euparal. From each slide two hundred fibre thickness measurements were made at random on a Zeiss Lanameter and the mean cross-sectional area

calculated from the mean square of the two hundred measurements, it being assumed for comparative purposes that the fibres were circular in cross-section. From the data on the breaking strength, the number of fibres broken, and the cross-sectional area, the tensile strength was calculated.

As regards the power of the diameter with which the breaking strength varies, Hardy (1920) asserted that the breaking strength of fine wool varied more closely with the first than with the second power of the diameter, while the breaking strength of coarse wool varied with a figure lying somewhere between the first and the second powers of the diameter. This assertion was tested on 114 merino samples by calculating the regression coefficient of the logarithm of the breaking strength on the logarithm of the diameter. The result was $1.895 (\pm 0.183)$ which is near enough to 2 to justify the assumption adopted for the present work that the breaking strength varies as the square of the fibre diameter.

RESULTS.

A. Fibres within the same Staple.

A portion of the work deals with the breaking strength and tensile strength of fibres within the same staple of Merino wool.

Twenty different Merino staples were selected and the coarse and fine fibres were separated from each other. Each lot of fibres separated was measured for fibre fineness and for straight fibre length. The high degree of correlation between the fibre fineness and the length of the fibres in the same staple shown by Duerden and Bosman (1931), viz. values from $+0.91$ to $+0.99$, was also evident in this series where the correlation was found to be $+0.7944$.

The results of the measurement of fibre fineness, breaking strength and tensile strength are summarised in Table 1.

The fibre fineness of the fine and coarse fibres of each staple is given in column 3. The mean breaking strengths per fibre are recorded in column 4 where the degree to which fine and coarse fibres in the same staple differ in breaking strength is demonstrated. The average breaking strength of the coarse fibres is $6.66 (\pm 0.504)$ grammes and that of the fine fibres is $4.38 (\pm 0.300)$ grammes. On an average the coarse fibres are 52 per cent. stronger per fibre than the fine fibres. When the same load is placed on the different fibres in the staple, the finer ones will break sooner and the coarser ones will stand a load of at least half as large again as do the finer fibres.

The practical application of these facts, whether during the processes of manufacture of wool fabrics, or during wear in wool garments, needs further investigation, although several authors have already contributed to the subject (Cowden, 1927; Williams, 1932, *et alia*). Williams in discussing the strength of textile fabrics, asserts that "the problems of strength were perhaps not so important in the past when fabrics were usually heavy and strong, but now that lighter and necessarily weaker fabrics are in demand

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and synthetic textile fibres of inferior strength to the natural fibres are extensively used, the strength problem is certainly of great importance."

TABLE 1.

The Results of the Measurement of Fibre Fineness, Breaking Strength and Tensile Strength of Fibres within the same Staple of Merino Wool.

Sample.	Type of Fibre Selected.	Mean Fineness. (μ).	Mean Breaking Strength per Fibre (gms.).	Mean Tensile Strength (gms. per sq. cm. \pm 10.
1	Fine.....	17.97	3.40	1.32
	Coarse.....	29.02	6.84	0.99
2	Fine.....	18.36	4.37	1.62
	Coarse.....	22.24	6.26	1.59
3	Fine.....	15.25	2.80	1.44
	Coarse.....	20.96	4.84	1.10
4	Fine.....	17.54	3.97	1.56
	Coarse.....	20.71	5.03	1.47
5	Fine.....	21.75	6.06	1.68
	Coarse.....	26.09	8.60	1.05
6	Fine.....	19.37	3.87	1.29
	Coarse.....	23.58	5.73	1.28
7	Fine.....	15.80	2.95	1.48
	Coarse.....	23.45	6.74	1.53
8	Fine.....	20.00	5.25	1.64
	Coarse.....	25.67	8.22	1.51
9	Fine.....	16.35	2.76	1.28
	Coarse.....	19.87	5.09	1.61
10	Fine.....	19.17	4.71	1.60
	Coarse.....	25.60	7.89	1.48
11	Fine.....	16.02	3.33	1.60
	Coarse.....	19.08	4.53	1.54
12	Fine.....	19.00	3.58	1.24
	Coarse.....	20.64	3.66	1.07
13	Fine.....	17.23	3.69	1.55
	Coarse.....	20.57	4.27	1.25
14	Fine.....	17.18	3.45	1.45
	Coarse.....	21.97	5.61	1.44
15	Fine.....	24.81	5.90	1.20
	Coarse.....	34.14	12.08	1.27
16	Fine.....	23.36	6.51	1.40
	Coarse.....	27.50	8.30	0.97
17	Fine.....	19.37	7.54	2.49
	Coarse.....	27.62	11.45	1.84
18	Fine.....	25.03	4.49	0.86
	Coarse.....	31.80	6.91	0.85
19	Fine.....	18.88	3.41	1.19
	Coarse.....	21.33	4.68	1.27
20	Fine.....	22.29	5.46	1.38
	Coarse.....	25.79	6.50	1.21

The point, whether large differences in fineness of the fibres in the same staple tend to give large differences in the breaking strength, was investigated. It was found that there was a coefficient of correlation of 0.853 between differences of these two characteristics, which finding is significant from a breeding aspect. It has

been shown by Duerden and Bosman (1931) that "a wool very variable in length will also be very variable in thickness, or a wool uniform in length will also be uniform in thickness. In striving for the uniformity of one attribute, the breeder will tend to attain uniformity of the other". One must then also conclude that the breeder, in striving for uniformity of fibre fineness, will tend to attain uniformity in fibre length and also in the breaking strength of the fibres.

As regards the tensile strength, given in the last column of Table 1, the average (expressed as grammes per square cm. $\times 10^6$) was $1.32 (\pm 0.058)$ for the coarse fibres and $1.46 (\pm 0.070)$ for the fine fibres. The difference (0.14 ± 0.054) is significant at the 5 per cent. probability level. The fine fibres within the same staple thus tend to have a higher tensile strength than the coarser ones.

The coefficients of correlation of the fibre characteristics within the same staple of Merino wool are summarised in Table 2.

TABLE 2.
Correlation Coefficients.

	Fibre Diameter.	Breaking Strength.	Tensile Strength.
Fibre Diameter....	—	+ .9508 (significant at 1 per cent.)	— .4822 (significant at 5 per cent.)
Breaking Strength..	+ .9508 (significant at 1 per cent.)	—	— .4338 (significant at 5 per cent.)
Tensile Strength....	— .4822 (significant at 5 per cent.)	— .4338 (significant at 5 per cent.)	—

There is a highly significant correlation between fibre diameter and breaking strength (.9508) and a significant negative correlation between fibre diameter and tensile strength (— .4822) and also between breaking strength and tensile strength (— .4338). The correlation between fibre diameter and tensile strength shows that the fine fibres in the staple have a higher tensile strength than the coarse fibres and suggests structural differences between the fine and coarse fibres of the staple, a point that is now being further studied from such aspects as breeding and nutrition.

In his work on "Fleece Density and the Histology of the Merino Skin" Carter (1939) has shown the existence of "primary" and "secondary" wool-producing follicles and it is probable that the coarse and fine fibres referred to above are produced respectively from the "primary" and "secondary" follicle and constitute two distinct types in the same staple.

B. Analysis of Different Samples.

A representative selection of 134 samples of South African Merino wool was analysed for breaking strength and tensile strength. The results of the two characteristics, arranged as frequency tables, are summarised respectively in Tables 3 and 4.

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TABLE 3.

The Average Breaking Strengths per Fibre of a selection of South African Merino Wool Samples.

<i>Group Interval (expressed as grammes).</i>	<i>Frequency.</i>
1 to 2	2
2 to 3	3
3 to 4	8
4 to 5	33
5 to 6	41
6 to 7	31
7 to 8	14
8 to 9	1
9 to 10	0
10 to 11	1

Mean: 5.50* grammes (at 70 per cent. Relative Humidity and 70° Fahrenheit).

Standard deviation: 1.357 grammes.

Coefficient of variability: 24.67 per cent.

The average breaking strength per fibre of the samples ranges from 1 gramme to 11 grammes with a mean of 5.50 grammes.

TABLE 4.

The Tensile Strength of a selection of South African Merino Wool Samples.

<i>Group Interval (expressed as grammes per square cm. $\times 10^6$).</i>	<i>Frequency.</i>
0.6 to 0.7	1
0.7 to 0.8	1
0.8 to 0.9	2
0.9 to 1.0	3
1.0 to 1.1	14
1.1 to* 1.2	24
1.2 to 1.3	41
1.3 to 1.4	27
1.4 to 1.5	19
1.5 to 1.6	2

Mean: $1.243 \dagger \times 10^6$ grammes per sq. cm.

Standard deviation: $\pm 0.1552 \times 10^6$ grammes per sq. cm.

Coefficient of variability: 12.49 per cent.

* or 5.95 grammes at 65 % Relative Humidity and 70° F.

† or 1.383×10^6 grammes per square centimetre at 65% Relative Humidity and 70° F.

The tensile strength of South African Merino wool samples varies from 0.6 to 1.6 ($\times 10^6$) grammes per square cm. with an average of 1.243 ($\times 10^6$) grammes per square cm. The latter figure can also be expressed as 8 tons per square inch or 12.4 kilogrammes per square millimetre.

The values for tensile strength, given in this paper, represent averages of large numbers of fibres (tested in bundles) and have a more direct bearing on general practice than those determinations that take into account only single fibres. It has been shown by Küsebauch (1937), who also discusses the advantage of bundle tests, that the average strength found by single fibre tests is 1.0799 times the value obtained by tests of bundles of 100 fibres.

CORRELATIONS.

A study of correlations in the range of South African samples shows that the coefficient of correlation between fibre fineness and breaking strength is $0.896(\pm 0.186)$ indicating a highly significant relationship between the two characteristics.

The value for this constant between fibre fineness and tensile strength is $-0.1780(\pm 0.0911)$ indicating an insignificant correlation.

It cannot, therefore, be said that in a random selection of Merino wool such as was used for the present study, the finer types have a higher or lower tensile strength than the coarser wools. This conclusion does not apply to fibres within the same staple (shown above) and it is likely that a random selection of wools from different sources would have undernourished as well as well-grown types, a factor which might reduce the value of a correlation coefficient. Further work on this aspect is now in progress.

The regression coefficient of the breaking strength on the fibre fineness is $0.445 (\pm 0.0208)$ indicating that on an average every increase of 1μ in fibre fineness is associated with an increase of approximately 0.445 grammes in the breaking strength. This value is valid over a limited range only, since the relation between breaking strength and fibre diameter is not linear.

SUMMARY AND CONCLUSIONS.

A series of South African Merino wool samples, representing wools from different parts of the Union, was analysed for breaking strength and tensile strength.

The method of determination, using Doehner's instrument, consisted of bundle tests, this giving average values for larger samples and lots.

A portion of the analysis is devoted to the breaking strength and tensile strength of fibres within the same staple. It is shown that the average breaking strength of the coarse fibres within the staple is 6.66 (± 0.504) grammes. That of the fine fibres is 4.38 (± 0.300) grammes, so that the coarse fibres are 52 per cent. stronger per fibre than the fine fibres. The practical significance of this is discussed.

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Breeding aspects are discussed and it is shown that the Merino breeder, in striving for uniformity of fibre fineness, will tend to attain uniformity in fibre length and also in the breaking strength of the fibres.

The average tensile strength of the coarse fibres within the staple is $1.32(\pm 0.058)$ and that of the fine fibres is $1.46(\pm 0.070)$, (expressed as grammes per square cm. $\times 10^6$). When fibres within the same staple are considered, there is a significant correlation of $0.9508(\pm 0.7938)$ between fibre diameter and breaking strength and a significant negative correlation of $-0.4822(\pm 0.0456)$ between fibre diameter and tensile strength.

The average breaking strength (per fibre) of representative South African Merino wool samples ranges from 1 to 11 grammes with a mean of 5.50 grammes.

The tensile strength of South African Merino wool varies from 0.6 to 1.6 ($\times 10^6$) grammes per square centimetre with an average of $1.243(\times 10^6)$ grammes per square centimetre of fibre. The latter figure can also be expressed as 8 tons per square inch or 12.4 kilogrammes per square millimeter of fibre.

When different samples are considered there is a significant correlation ($r=0.896\pm 0.0186$) between fibre fineness and breaking strength, but an insignificant correlation ($r=-0.1780\pm 0.0911$) between fibre fineness and tensile strength.

The regression coefficient of the breaking load on fibre fineness is $0.445(\pm 0.0208)$ indicating that, on an average, every increase of 1μ in fibre fineness is associated with an increase of 0.445 grammes in the breaking strength.

ACKNOWLEDGEMENT.

The authors are indebted to the South African Wool Council for assistance in carrying out the work. This forms a part of a project on "The Basic Characteristics of South African Merino Wool" which is financed by the Wool Council out of Wool Levy Funds.

BIBLIOGRAPHY.

- ANERT, H. (1929). Ein Beitrag zur Kenntnis der mechanischen Eigenschaften gesunder Wollhaare von Merinokammwolljahrlingen. *Dissertation, Berlin*.
- BARKER, S. G., AND HEDGES, J. J. (1927). Effect of humidity on the breaking strength and extension of worsted yarns. *B.R.A. publication* No. 80.
- BOSMAN, V. (1937). Biological studies on South African merino wool production. *J. Text. Inst.*, Vol. 28, No. 8, p. 270.
- CARTER, H. B. (1939). Fleece density and the histology of the merino skin. *The Austral. Vet. Journ.*, p. 210.
- CONSTANTINESCU AND CONTESCU (1928). Untersuchungen über Tragkraft und Dehnbarkeit der Wolle beim Zigajaschaf. *Zeits. Tierz. u. Züchtungsbiol.*, Vol. II.
- COWDEN, W. J. (1927). The tensile strength of yarns and fabrics. *J. Text. Inst.*, Vol. 18, No. 3, pp. 58-61.

- CUNLIFFE, P. W. (1933). Wool fibre: Stretching, twisting and swelling phenomena. *J. Text. Inst.*, Vol. 24, No. 12, p. T. 417.
- DEPPE, E. (1926). Reiz- und Knickfestigkeit gesunder Wollhaare. *Zeits. f. Tierz. u. Züchtungsbiol.*, Vol. 7.
- DIMITRIADIS, I. M. (1926). Die physikalischen Eigenschaften der Merino-jährlingswolle aus der Stammschäferei Friedeburg a.d.s. *Dissertation. Halle.*
- DOEHNER, H. (1932). Eine neue Methode zur Feststellung von Bruchfestigkeit und Bruchdehnung einer bestimmten Anzahl von Wollhaaren oder anderen Textilfasern. *Zeits. Züchtungskunde*, Vol. 7, No. 5, p. 179.
- DOEHNER, H. (1935). Die Feinheit und Festigkeit der Deutschen Schafwollen. Paul Parey, Berlin.
- DUERDEN, J. E., AND BOSMAN, V. (1931). Fibre lengths, thicknesses and qualities in a single wool staple. *17th Report of the Dir. Vet. Serv. and An. Ind.*, Part 2, pp. 771-779.
- EWLES, J., AND SPEAKMAN, J. B. (1928). The fine structure of wool. *Nature*, Vol. 122, No. 3071, p. 346.
- EWLES, J., AND SPEAKMAN, J. B. (1930). Examination of the fine structure of wool by X-Ray analysis. *Proc. Roy. Soc.*, Vol. B.105, p. 600.
- GULDENPFENNIG, H. (1915). Studien über die Beschaffenheit der Wolle von reinblutigen Schafen und Somali-Kreuzungen. *Dissertation, Halle.*
- HARDY, J. I. (1918). Influence of humidity upon the strength and the elasticity of wool fibre. *J. Agric. Research.*, Vol. 14, No. 8, p. 285.
- HARDY, J. I. (1920). Further studies on the influence of humidity upon the strength and elasticity of wool fibre. *J. Agric. Research.*, Vol. 19, No. 2, p. 55.
- HILL, J. A. (1908). Report of the wool specialist. *Wyoming Agric. Stn. Report.*
- HILL, J. A. (1911). Studies on the strength and elasticity of the wool fibre. The probable error of the mean. *Wyoming Agric. Stn. Report.*
- HILL, J. A. (1912). The value of fibre testing machines for measuring the strength and elasticity of wool. *Wyoming Agric. Stn.*, Bul. 92.
- KÄRRNER, H. (1932). Weitere Untersuchungen über Tragkraft und Dehnung des Wollhaares mittels des Tänzer-Polikeitschen Dynamometers. *Zeits. f. Züchtung. Reihe. B.*, Vol. 23, No. 3, p. 377.
- KRAIS, P. (1927). Untersuchungen über die Wolle. *Textil Forschung*, Vol. 9, No. 3, p. 105.
- KRONACHER, C. (1924). Neues über Haar und Wolle. 1-11 Teil. *Zeits. f. Tierz. u. Züchtungsbiol.*, Vol. 1.
- KÜHLER, H. (1924). Untersuchungen über die physikalischen Eigenschaften der Wolle van Karakulschafen. *Dissertation. Halle.*
- KUSEBAUCH, K. (1937). Wool Fibre Strength Tests: Comparison of single fibre and bundle tests. *Textilberichte*, Vol. 18, No. 29.
- McMURTRIE, W. (1886). Report upon an examination of wools and other animal fibres. *U.S.A. Dept. of Agric.*, Washington.
- MATTHEWS, J. M. (1904). The textile fibres. Wiley and Sons, New York, p. 20, p. 272.
- MILLER, R. F., AND TALLMAN, W. D. (1915). Tensile strength and elasticity of wool. *J. Agric. Research*, Vol. 4, No. 5, p. 379.
- OGRIZEK, A. (1926). Ein Beitrag zur Kenntnis der Beziehungen zwischen den physikalischen Eigenschaften der Wolle. *Zeits. f. Tierz. u. Züchtungsbiol.*, Vol. 7.

BASIC CHARACTERISTICS OF MERINO WOOL.

- REIMERS, J. H. W. TH., AND SWART, J. C. (1930). Relations between the diameter, the extensibility and the carrying capacity of wool fibres. *Annals. Univ. Stellenbosch*, Vol. 8, A.3.
- SAUR, A. (1931). Tensile testing machines: Rate of break. *Spinn. u. Web.*, Vol. 49, No. 52, p. 1.
- SCHMIDHAUSER, O. (1936). Textile fibres: strength. *Textilberichte*, Vol. 17, pp. 905-910.
- SPEAKMAN, J. B. (1924). The extensibility of the wool fibre. *J. Text. Inst.*, Vol. 15, No. 11, p. T.529.
- SPEAKMAN, J. B. (1926). The gel structure of the wool fibre. *J. Text. Inst.*, Vol. 17, No. 9, p. T.457.
- SPEAKMAN, J. B. (1926). The extension of wool fibres under constant stress. *J. Text. Inst.*, Vol. 17, No. 9, p. T.472.
- SPEAKMAN, J. B. (1927). The intracellular structure of the wool fibre. *J. Text. Inst.*, Vol. 18, p. T.431.
- SPEAKMAN, J. B. (1928). The plasticity of wool. *Proc. Roy. Soc.*, B.103, p. 377.
- SPEAKMAN, J. B. (1929). Elasticity of wool. *Nature*, Vol. 124, p. 948.
- SPEAKMAN, J. B. (1929). The elastic properties of wool in water at high temperatures. *Trans. Farad. Soc.*, Vol. 25, No. 95, p. T.4.
- SPEAKMAN, J. B. (1929). The rigidity of wool and its change with adsorption of water vapour. *Trans. Farad. Soc.*, Vol. 25, p. 92.
- SPEAKMAN, J. B. (1929). Stretched wool fibre: Regain and porous structure. *Nature*, Vol. 124, p. 411.
- SPEAKMAN, J. B. (1930). The adsorption of water by wool. *J. Soc. Chem. Ind.*, Vol. 49, No. 18, p. 209T.
- SPEAKMAN, J. B. (1930). Elastic properties of wool in organic liquids. *Trans. Farad. Soc.*, Vol. 26, No. 105, p. 61.
- SPEAKMAN, J. B. (1930). The action of caustic soda on wool. *J. Soc. Chem. Ind.*, pp. 321T-324T.
- SPEAKMAN, J. B. (1930). The micelle structure of the wool fibre. *Nature*, Vol. 126, p. 565.
- SPEAKMAN, J. B. (1931). The micelle structure of the wool fibre. *Proc. Roy. Soc.*, Vol. A.132, p. 167.
- TANZER, E. (1926). Weitere Untersuchungen über die physikalischen Eigenschaften der Wolle. *Zeits. Tierz. u. Züchtungsbiol.*, Vol. 7.
- WILLIAMS, J. G. (1932). The strength of textile fabrics and their satisfaction-giving qualities in conditions of normal use. *J. Text. Inst.*, Vol. 23, No. 7, pp. 161-170.

Studies on the Basic Characteristics of South African Merino Wool.—II. Specific Gravity.

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INTRODUCTION.

RESEARCH workers are inclined to believe that the variability of the specific gravity of wool is so small as to be of no practical significance. King (1926) asserted that "the values indicate that the specific gravity is substantially the same for all qualities which are medulla-free". Speakman, Stott and Chang (1933) found the extreme values of 1.304 for Wensleydale and 1.309 for Merino wool at 25° C. Notwithstanding these results practical sheep and woolmen believe that there are marked differences in the specific gravities of different types of wool and even in the different types within the Merino. Provision is also made for this contention in some wool score cards. As a result of these divergent viewpoints, a study of the variation in specific gravity of South African Merino wool was undertaken.

METHOD.

The bulk of the grease and dirt of the selected wool samples was removed by a preliminary washing in benzene at 50° C., after which adhering foreign matter was removed with the aid of forceps. Further purification was effected by successive extraction with benzene, alcohol and ether in a soxhlet apparatus. Finally the wool was washed in a 0.1 per cent. solution of saponin at 50° C. for 10 minutes and repeatedly rinsed in distilled water.

Four specific gravity bottles, each containing approximately two grams of wool, were placed above a shallow dish containing phosphorus pentoxide in a Witts filtering apparatus from which the funnel had been removed and a ground-in joint inserted (Fig. 1). A glass tube passing through the ground-in joint was joined to four narrower tubes each of which projected into a specific gravity bottle. On the outside of the apparatus the tube was bent downwards, drawn to a point and sealed off.

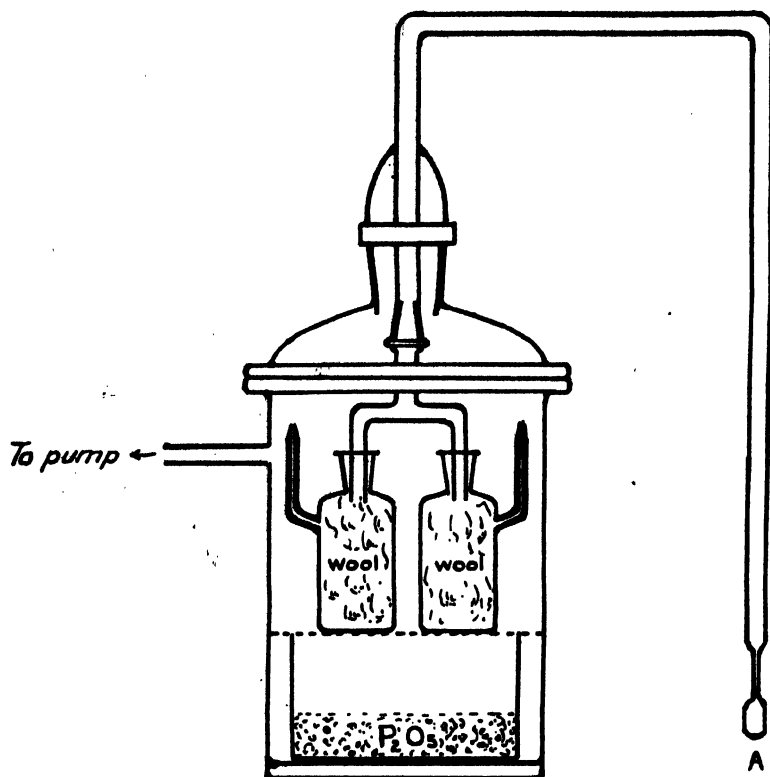


FIGURE 1.

The apparatus was evacuated through the side tube to a pressure of 0.003 mm. of mercury by means of a mercury vapour pump backed by a Hyvac pump, evacuation being continued for a fortnight. At the end of this period the tip of the tube leading from the apparatus was broken under benzene, which had been freshly distilled over sodium after a preliminary drying over calcium chloride and phosphorus pentoxide.

The bottles containing wool and benzene were weighed after immersion at various temperatures between 15° C. and 30° C. in a thermostatically controlled waterbath, the temperature of which was kept constant within 0.1° C.

The wool was then removed and the bottles were filled from the same batch of benzene and weighed over the same range of temperatures as before. Since the relation between the weights of the bottles filled with benzene and temperature could be regarded as linear over this range of temperature, a linear equation was fitted to the results by the method of least squares. The weights of the bottles filled with benzene were then calculated for the same temperatures at which the bottles had been weighed when containing both wool and benzene.

The bottles had to be calibrated anew with benzene after each determination since the relation between the weight of the bottle filled with benzene and temperature varied with time.

The bottles were then filled with water and weighed and the specific gravity of the benzene calculated. In all cases the value of the specific gravity of the benzene agreed to within 0.02 per cent. of the values given in the International Critical Tables.

The dry weight of the wool was subsequently determined by heating to a temperature of 100° C. at 5 cm. Hg. pressure in the presence of concentrated sulphuric acid. An Abderhalden drying apparatus was used for this purpose.

Extreme care was exercised to ensure that the benzene used was pure and dry since the observed specific gravity would be the apparent and not the true specific gravity if traces of water or other liquids present in the benzene were adsorbed by the wool. The sorptive effect was found by King (1926) to be a minimum with benzene, toluene, nitrobenzene, olive oil and oleic acid.

Owing to the large variations in air density experienced, it was found necessary to apply a correction for buoyancy at each weighing. This was accomplished by taking a reading of the pressure, temperature and relative humidity of the air at each weighing and calculating the air density (Watson 1922), while the external volumes of the bottles were determined by an immersion method.

In order to ensure that inadequate drying of a particular batch of benzene or a possible error in the calibration of a particular bottle should not influence the result, determinations were carried out on duplicate samples, using a different batch of benzene and a different bottle each time.

A determination of the specific gravity of 50 samples in duplicate gave ± 0.00116 for the standard error of the means of duplicates, a value small enough to demonstrate such differences between samples as have a practical value.

The results are all expressed as the specific gravity at 25° C. relative to water at 4° C.

EXPERIMENTAL RESULTS.

The specific gravity of a series of samples drawn from the various wool-growing areas was determined. These samples differed considerably in regard to other physical properties and consequently were expected to show differences in specific gravity, if such differences existed.

The results are given in Table 1.

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TABLE 1.

Sample.	Specific Gravity at 25°/Water at 4° C.	Mean Fineness. (μ).	Origin.
1	1.303	20.7	Karoo.
2	1.306	19.2	"
3	1.302	21.6	"
4	1.304	24.4	" (Ram).
5	1.311	25.1	"
6	1.303	27.3	Karoo (Ram).
7	1.305	22.0	Karoo (Ram).
8	1.305	22.4	Karoo (Ram).
9	1.303	23.4	Karoo (Ram).
10	1.300	22.8	Karoo (Ram).
11	1.301	—	Karoo (Ram).
12	1.301	—	Karoo (Ram).
13	1.303	—	Karoo (Ram).
14	1.301	—	Karoo (Ram).
15	1.303	—	Grassveld (Eastern Province).
16	1.303	—	Grassveld (Eastern Province).
17	1.298	—	Grassveld (Eastern Province).
18	1.301	—	Grassveld (Eastern Province).
19	1.301	19.4	Grassveld (Eastern Province).
20	1.304	—	Sour Grassveld (Orange Free State) (Ram).
21	1.305	—	Sour Grassveld (Orange Free State) (Ram).
22	1.309	—	Sour Grassveld (Orange Free State) (Ram).
23	1.309	—	Sour Grassveld (Orange Free State) (Ram).
24	1.310	—	Sour Grassveld (Orange Free State) (Ram).
25	1.313	—	Sour Grassveld (Orange Free State) (Ram).
26	1.311	—	Sour Grassveld (Orange Free State) (Ram).
27	1.313	—	Sour Grassveld (Orange Free State) (Ram).
28	1.298	17.6	Grassveld (Transvaal Highveld).
29	1.304	19.9	Grassveld (Transvaal Highveld).
30	1.302	19.8	Grassveld (Transvaal Highveld).
31	1.301	20.6	Grassveld (Transvaal Highveld) (Lamb's Wool).
32	1.308	19.4	Western Cape Province.
33	1.308	19.8	Western Cape Province ("Wild Wool").
34	1.303	19.0	Western Cape Province ("Cotton-fibred Wool").
35	1.305	20.5	Experimental Wool (Well-fed).
36	1.304	23.1	Experimental Wool (Well-fed).
37	1.307	23.7	Experimental Wool (Well-fed).
38	1.304	26.2	Experimental Wool (Well-fed).
39	1.308	22.1	Experimental Wool (Well-fed).
40	1.307	19.4	Experimental Wool (Well-fed).
41	1.312	23.7	Experimental Wool (Well-fed).
42	1.306	22.8	Experimental Wool (Well-fed).
43	1.308	25.7	Experimental Wool (Well-fed).
44	1.307	26.7	Experimental Wool (Well-fed).
45	1.304	15.7	Experimental Wool (Underfed).
46	1.307	15.6	Experimental Wool (Underfed).
47	1.306	19.9	Experimental Wool (Underfed).
48	1.307	16.1	Experimental Wool (Underfed).
49	1.308	12.9	Experimental Wool (Underfed).
50	1.306	19.1	Experimental Wool (Underfed).
51	1.305	16.5	Experimental Wool (Underfed).
52	1.308	17.7	Experimental Wool (Underfed).
53	1.306	15.8	Experimental Wool (Underfed).
54	1.304	15.6	Experimental Wool (Underfed).

Mean..... = 1.3052/water at 4° C.

Standard Deviation..... = \pm 0.0035.

Coefficient of Variability..... = 0.27 per cent.

Standard error of a determination (mean of duplicates)..... = \pm 0.0012.

An analysis of variance was made of the results, as shown in Table 2.

TABLE 2.
Analysis of Variance (Specific Gravity of 50 Samples).

Variance.	D.F.	Standard Deviation.	z.
Between samples.....	49	·004993	1·112.
Within samples.....	50	·001643	$n_1 = 49, n_2 = 50.$

The value of z is highly significant at the 0·1 per cent. probability level, showing that definite differences in specific gravity exist among the samples.

Owing to the small range of temperature, (15° C.-30° C.), over which determinations were made, the coefficient of expansion could not be estimated with any degree of accuracy. The mean value obtained was $(1·5 \pm 0·27) \times 10^{-4}$, which is of the same order as that obtained for 60's Merino wool by Speakman, Stott and Chang (1933).

The correlation coefficient between specific gravity and fibre fineness was $+0·0049 \pm 0·16$, an insignificant value.

The next point investigated was the assertion that wools could be selected according to specific gravity.

A series of samples from stud rams was specially selected in pairs by a leading sheep and wool expert, who presumed that the samples of a pair were similar except for differences in specific gravity. The samples were all grown on the same pasturage.

The results of the determinations are given in Table 3.

TABLE 3.

Pairs.	Presumed of Lower S.G.	Presumed of Higher S.G.	Difference.
1.....	1·304	*	—
2.....	*	1·305	—
3.....	1·309	1·309	0
4.....	1·310	1·313	+ ·003
5.....	1·311	1·313	+ ·002

* Samples submitted were too small for a determination.

Only in the case of the fourth pair do the results definitely agree with a view that the samples of a pair have been selected according to specific gravity.

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A further set of four samples was selected from another area, all being from the same flock and grown under identical conditions. These were numbered from one to four in decreasing values of specific gravity (i.e. No. 1 highest and No. 4 lowest). The results are given in Table 4.

TABLE 4.

Sample.	Specific Gravity.
Presumed higher 1.....	1·301
" " 2.....	1·301
" " 3.....	1·303
Presumed lower 4.....	1·301

Table 4 does not support the view that the samples were correctly chosen.

Four more samples were selected and numbered one to four in decreasing values of specific gravity. The results are given in Table 5.

TABLE 5.

Samples.	Specific Gravity.
Presumed higher 1.....	1·303
" " 2.....	1·303
" " 3.....	1·298
Presumed lower 4.....	1·301

The results of Table 5 show a tendency to support the view that the samples were correctly chosen.

DISCUSSION.

The determination of the specific gravity of fifty-four samples of South African Merino wool showed that real differences in specific gravity occurred. The values varied from 1·298 to 1·313 but the small coefficient of variability shows that specific gravity may be regarded as one of the least variable attributes of Merino wool. As will be seen from Table 1 the samples represented most of the wool-growing areas and even the wool from the experimental animals may be regarded as typical cases occurring in practice. The standard error of the mean of all the samples was $\pm 0\cdot0005$, which was so small as to suggest that a fair average for South African Merino wool had been determined.

With regard to the suggestion made by Speakman, Stott and Chang (1933) that the differences in the specific gravity obtained by them for Australian 60's Merino wool and that found by King (1926) may have been due to a difference in the methods of evacuation, it may be pointed out that both values lie within the range obtained for South African Merino wool in this investigation.

It will be noted that the results of Table 3 are all higher than those given in Tables 4 and 5. The samples within each group were grown under identical conditions but the groups themselves represented different areas, so that it is reasonable to suppose that environment or breeding had influenced the specific gravity of the wool. Until further results are available no conclusions can be drawn.

Evidence regarding the assertion that wools can be selected according to specific gravity is inconclusive, and while a larger number of samples is necessary in order to prove or disprove the theory, it appears probable at this stage that the samples had been selected for some other property mistakenly assumed to be specific gravity. This point is now being further investigated.

The specific gravity of clean wool enters into the estimation of fibre fineness in the weight-length method, and has been assumed to have a value of 1.30 (Roberts 1930). By this method the fineness of a sample having a specific gravity of 1.313 will be estimated too low by $\frac{1}{2}$ per cent. or 0.1μ in the case of a medium merino wool. Since this error is small compared to that found in the length measurements for the method employed by Roberts, it is evident that variations in the specific gravity are not a serious source of possible error.

SUMMARY AND CONCLUSIONS.

1. The specific gravity of 54 samples of South African Merino wool from various wool-growing areas was determined. Significant differences occurred among these samples.

2. The mean value was 1.3052 at 25°C., water at 4°C. with a standard deviation of ± 0.0035 and a coefficient of variability of ± 0.27 per cent.

3. A series of samples presumed to have been selected for differences in specific gravity were analysed. The results were inconclusive.

4. No correlation between the specific gravity and the fibre fineness of the samples was obtained.

5. The influence of variations in specific gravity on the determination of fibre fineness by the weight-length method is discussed.

ACKNOWLEDGMENTS.

The authors wish to acknowledge their indebtedness to Dr. V. Bosman for his help and interest in the investigation.

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The authors are also indebted to the South African Wool Council for financial assistance. (This paper forms part of a project on "Studies on the Basic Characteristics of South African Merino Wool", which is financed by the Wool Council out of Wool Levy Funds.)

REFERENCES.

- KING, A. T. (1926). The Specific Gravity of Wool and its Relation to Swelling and Sorption in Water and other Liquids. *J. Text. Inst.*, Vol. 18, No. 1, pp. T.53-T.67.
- ROBERTS, J. A. F. (1930). Fleece Analysis for Biological and Agricultural Purposes. I. The Average Fineness of a Sample of Wool. *J. Text Inst.*, Vol. 21, No. 4, pp. T.127-T.164.
- SPEAKMAN, J. B., STOTT, E., AND CHANG, H. (1933). A Contribution to The Theory of Milling, Part 2. *J. Text. Inst.*, Vol. 24, No. 7, pp. T.273-T.292.
- WATSON, W. (1922). A Textbook of Practical Physics, 3rd. Ed., p. 77.

Studies on the Basic Characteristics of South African Merino Wool. III.—Moisture Adsorption.

By C. M. VAN WYK, Wool Research Section, Onderstepoort.

INTRODUCTION.

WOOL adsorbs moisture readily from the surrounding atmosphere, the amount adsorbed being greater than in the case of other textiles. This characteristic plays an important part in enhancing the suitability of wool as a clothing material. Also since the moisture content has a marked influence on its physical properties, the testing of wool for various attributes has to be carried out under controlled conditions of humidity and temperature.

Several authors have studied the adsorption of moisture by wool, the most notable contributions being those of Speakman (1930) and Speakman, Stott and Cooper (1936). It was shown that a marked hysteresis exists in the moisture content of wool between adsorption and desorption conditions. In dealing with six different types of wool, Speakman (1930) asserted that "the adsorptive powers of different wools are remarkably similar, and such differences as do exist may be generalised in the statement that the affinity for water appears to increase slightly as the wool becomes coarser".

Although the work recorded deals with wool from different breeds and sources, no direct investigation has previously been made of the moisture adsorptive capacity of South African Merino wool or of possible differences in this characteristic among different types of South African Merino wool.

Studies of this nature would establish the moisture adsorptive capacity of South African Merino wool and would indicate to what extent the testing of wool is reliable under controlled conditions of humidity and temperature. Appreciable differences in the moisture adsorptive capacity of merino wool would also have a bearing on clean yield determinations. The present paper is the result of a preliminary investigation into differences in adsorptive powers of different types of South African Merino wool.

EXPERIMENTAL PROCEDURE.

Two samples for duplicate determinations were drawn from each of ten types of South African Merino wool selected for their

widely differing properties. The bulk of the grease and dirt was removed by a preliminary washing in cold benzene, after which adhering foreign matter was carefully extracted by hand with the aid of finely pointed forceps. The wool was then purified by extraction in succession with benzene, alcohol and ether in a Soxhlet apparatus, and finally washed in several changes of distilled water, to the first of which 0.1 per cent. saponin had been added. When air dry, each sample was placed in a regain bottle of the type described by Barritt and King (1926).

A current of air from a water blower was allowed to pass slowly through four flasks in succession. The second, third and fourth of these each contained a litre of a solution of sulphuric acid made up to a definite concentration. The solution in the first flask was of a slightly higher concentration in order to reduce the high moisture content of the air from the water blower. After passing through the four solutions the current of air was divided into five portions. Each portion passed in succession through a spray trap, a regain bottle containing wool, and finally through a trap containing a solution of the same concentration as before. The last trap served the double purpose of preventing access of moisture from the surrounding atmosphere and of allowing for the adjustment of the rate of flow of air through each regain bottle separately. The whole apparatus was placed in a constant humidity chamber, the temperature of which was maintained at 21.1°C . The generation of the airstream by pressure instead of suction reduced the possibility of leakage of the surrounding air into the system.

The solutions were successively diluted to correspond to relative humidities of 20 per cent., 40 per cent., 60 per cent., 80 per cent., 90 per cent. and 97.5 per cent. according to data given by Wilson (1921). Observations beyond 97.5 per cent. relative humidity were considered impracticable owing to condensation of moisture on the wool as a result of small unavoidable temperature fluctuations. Before exposing the samples to the air current at each humidity they were subjected to a current of dry air so as to ensure adsorption conditions.

The regain bottles were weighed daily and when the weights became constant, weighing was continued for another five days, each bottle being allocated to a different portion of the airstream between weighings. This was to ensure that the humidity of any portion of the stream of air had not been affected during its passage through the trap or connecting tubing. In order to allow for possible changes in weight of the bottles the wool was removed and the bottles weighed separately after constancy at each humidity had been obtained. The specific gravity of the solutions was checked at frequent intervals with the aid of a Westphal balance. No appreciable changes in the solutions occurred. Desorption was studied at 80 per cent., 60 per cent., 40 per cent. and 20 per cent. relative humidities.

Finally the dry weights of the samples were determined by heating to 100°C . at 5 cms. Hg. pressure in the presence of sulphuric acid, an Abderhalden drying apparatus being used for the purpose.

RESULTS.

Table 1 gives the amount of moisture adsorbed by the ten samples at each humidity, expressed as a percentage of the dry weight of the wool. The mean values are plotted in Fig. 1.

TABLE 1.

Sample.	RELATIVE HUMIDITY.					
	20 Per cent.	40 Per cent.	60 Per cent.	80 Per cent.	90 Per cent.	97.5 Per cent.
			Adsorption.			
1.....	6.6	10.0	14.2	19.2	23.0	28.2
2.....	6.4	9.7	13.8	18.6	22.5	28.1
3.....	6.5	9.8	13.9	18.7	22.3	27.4
4.....	6.6	9.9	14.1	19.1	22.9	28.1
5.....	7.4	10.9	15.0	20.1	24.0	28.3
6.....	6.9	10.2	14.3	19.0	22.5	27.2
7.....	6.9	10.2	14.4	19.2	22.7	27.7
8.....	6.8	10.1	14.3	19.1	22.7	27.8
9.....	6.6	10.0	14.5	19.3	23.1	28.2
10.....	6.7	10.0	14.3	19.0	22.6	27.5
MEAN.....	6.7	10.1	14.2	19.1	22.8	27.9
			Desorption.			
1.....	8.1	12.3	16.0	20.9	—	—
2.....	7.9	11.8	15.3	19.7	—	—
3.....	7.9	12.0	15.4	19.7	—	—
4.....	8.1	12.3	15.6	20.2	—	—
5.....	8.4	12.7	16.2	21.0	—	—
6.....	8.3	12.2	15.9	20.2	—	—
7.....	8.2	12.1	15.8	20.4	—	—
8.....	8.2	12.2	16.0	20.3	—	—
9.....	8.0	12.2	16.1	20.6	—	—
10.....	8.0	12.1	15.7	20.3	—	—
MEAN.....	8.1	12.2	15.8	20.3	—	—

An analysis of the variance of the results is given in Table 2.

TABLE 2.
Analysis of Variance.

Variance.	D.F.	Sums of Squares.	Mean Squares.	S.D.	Log S.D.
Between samples.....	9	11.2242	1.246935	1.1166	0.1101
Between humidities.....	5	6319.68742	—	—	—
Error.....	45	3.88508	0.086335	0.2938	-1.2249
Between totals of duplicates..	50	6334.79492	—	—	—
Within totals of duplicates...	60	3.24500	0.054083	0.2325	-1.4592
TOTAL.....	119	6338.03992	—	—	—

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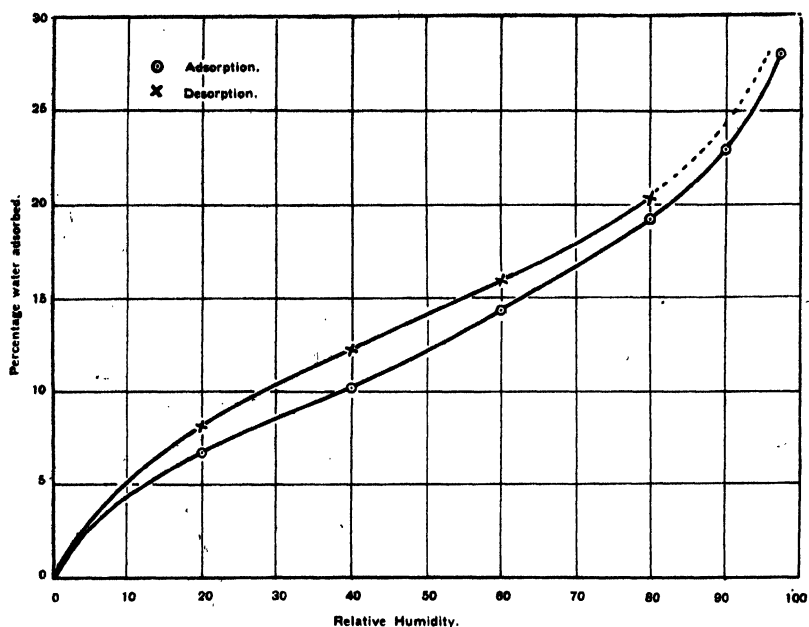


Fig. 1.

The variance between samples differs significantly from the error variance at $P = .001$, while the error variance does not differ significantly from the variance within duplicate determinations at $P = .05$. The existence of definite differences between the adsorptive capacities of the different types of wool considered is thus proved. According to Table 2, the standard error of the mean of duplicates is $0.2325/\sqrt{2}$ or 0.1644 , a value which is satisfactory for the purpose of the present study.

The greatest difference was found in the case of samples 3 and 5, the results for which are given in Table 3.

TABLE 3.

Sample.	RELATIVE HUMIDITY.					
	20 Per cent.	40 Per cent.	60 Per cent.	80 Per cent.	90 Per cent.	97.5 Per cent.
3.....	6.5	9.8	13.9	18.7	22.3	27.4
5.....	7.4	10.9	15.0	20.1	24.0	28.3
DIFFERENCE....	0.9	1.1	1.1	1.4	1.7	0.9

At all values of the relative humidity, sample 5 adsorbed more moisture than sample 3, the excess being of the order of 1 per cent. of the dry weight.

The variation in adsorptive capacity of the ten samples at the different values of relative humidity is illustrated in Table 4.

TABLE 4.

Relative humidity.	20%	40%	60%	80%	90%	97.5%
Standard deviation	0.29	0.31	0.35	0.39	0.48	0.37

While the standard deviation increases with humidity up to 90 per cent. relative humidity, the value at 97.5 per cent. relative humidity shows a slight decrease and corresponds with that at approximately 80 per cent. relative humidity.

The wools used were representative of types that differ among themselves in other physical properties. The averages of the experimental results are therefore only applicable to the series and do not represent the average adsorptive capacity of the South African Merino wool clip.

The samples, which gave the lowest and highest values (viz. Nos. 3 and 5, Table 1) were a "ropy" type and an extremely hairy type respectively, wools that form a small portion of the South African clip. The influence of these two samples on the variation found is evident when they are omitted in the calculation of the standard deviation, which at 90 per cent. relative humidity is then halved. It can thus be reasonably presumed that the average of the South African clip lies between the limits given by these types and will not differ greatly from the average of the values given in Table 1.

Except for the fact that the extremely hairy sample gave the highest values, the results do not follow Speakman's (1930) observation that the affinity for water appears to increase slightly as the wool becomes coarser, though this difference may be due to the fact that Speakman used wools from different breeds of sheep whilst the present study confines itself to Merino types only.

Differences in the amount of water adsorbed at any value of the relative humidity have an important bearing on the method of estimating the regain of samples by weighing them under the same conditions as a standard sample of known dry weight. This method is used for large-scale determinations of the clean yields of fleeces where the final results have to be expressed in terms of a definite regain.

Roberts (1930) suggested that a standard sample should be made up of a number of smaller samples taken from different wools. Applying this principle to the ten wools used in the present study,

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a standard sample may be supposed to have been made up of equal portions taken from all the samples, and the ten samples weighed together with the standard at 60 per cent. relative humidity. If the dry weights of the samples are calculated on the assumption that all contain the same amount of moisture as the standard, then the errors due to different adsorptive powers have a standard deviation of ± 0.2857 per cent. This means that an error exceeding 0.3 per cent. of the dry weight will occur once in every third case. The three samples of which the dry weight estimates differed from the true values by more than 0.3 per cent. consisted of the hairy and "ropy" types already mentioned. In cases such as occur in the laboratory, a selection of samples will rarely contain so high a proportion of these types and will often lack them altogether. It can, therefore, be concluded that the standard sample method of estimating regain is satisfactory when an accuracy greater than 0.2 per cent. is not required; as in the case of clean yield determinations provided that samples of the hairy and "ropy" types are not included in the series under examination.

SUMMARY AND CONCLUSIONS.

The adsorption of moisture at various relative humidities by ten samples representing different types of South African Merino wool was investigated.

The samples differed significantly in adsorptive powers. At 90 per cent. relative humidity the extreme values of 24.0 per cent. and 22.3 per cent. with a mean value of 22.8 per cent. were obtained. At 97.5 per cent. relative humidity the corresponding values were 28.3 per cent. and 27.4 per cent., showing a smaller difference than at 90 per cent. relative humidity. The highest values were obtained in the case of an extremely hairy sample, and the lowest in the case of a sample of the "ropy" type.

The use of a standard sample for estimating the dry weights of samples is discussed. It is concluded that the method is suitable where an accuracy greater than 0.2 per cent. is not required, provided that samples of the hairy and "ropy" types are not included.

ACKNOWLEDGMENTS.

The author wishes to record his appreciation to Dr. V. Bosman for his interest and assistance during the investigation.

This paper forms part of a project on "Studies on the Basic Characteristics of South African Merino Wool", which is financed by the Wool Council out of Wool Levy Funds.

REFERENCES.

- BARRITT, J., AND KING, A. T. (1926). The sulphur content of wool. Part I. Inherent variations according to the type of wool. *J. Text. Inst.*, Vol. 17, No. 8, pp. T386-T395.

- ROBERTS, J. A. F. (1930). Fleece analysis for biological and agricultural purposes, I. The average fineness of a sample of wool. *J. Text. Inst.* Vol. 21, No. 4, pp. T127-164.
- SPEAKMAN, J. B. (1930). The adsorption of water by wool. *J. Soc. Chem. Ind.* Vol. 49, No. 18, pp. 209T-213T.
- SPEAKMAN, J. B., AND COOPER, C. A. (1936). The adsorption of water by wool. Part I. Adsorption hysteresis. *J. Text. Inst.*, Vol 27,, No. 7, pp. T183-T185.
- SPEAKMAN, J. B., AND STOTT, E. (1936). The adsorption of water by wool. Part II. The influence of drying conditions on the affinity of wool for water. *J. Text. Inst.*, Vol. 27, No. 7, pp. T186-T190.
- SPEAKMAN, J. B., AND COOPER, C. A. (1936). The adsorption of water by wool. Part III. The influence of temperature on the affinity of wool for water. *J. Text. Inst.*, Vol. 27, No. 7, pp. T191-T196.
- WILSON, R. E. (1921). Humidity control by means of sulphuric acid solutions, with critical compilation of vapour pressure data. *J. Ind. Eng. Chem.*, Vol. 13. No. 4. p. 326.

Section VII.

Solar Survey.

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South African Solar Radiation Survey 1937-38.

By GERTRUD RIEMERSCHMID, Union Department of
Public Health.

AN INVESTIGATION ENDOWED BY DR. H. MERENSKY.

FOREWORD.

In 1935 my attention was drawn to the fact that one of the members of the scientific staff of the Jena University Institute of Physical Therapeutics was making investigations on the solar radiation in Kenya. As lack of knowledge regarding this subject in South Africa was a serious deficiency in our public health armamentarium the opportunity was seized for getting some information on the matter. We had long realised that we were woefully ignorant of the nature and value of our sunlight and of its possible influence on human, plant and animal life and health. Miss Riemerschmid, the worker in question was, therefore, invited by the Union Government to extend her tour to the South. She was fortunately able to spend some months in the Union taking readings, more particularly at the Nelspoort Tuberculosis Sanatorium and near the site in Durban where the Government was about to erect the King George V Tuberculosis Hospital.

These preliminary investigations revealed striking information. It appeared that our sunlight had greater therapeutic value than that at some of the best-known health resorts of the world. It became more than ever desirable that exact information regarding these rays should be obtained.

The money available for health work in the Union was limited. For abstruse investigations of this kind none could be made available while other more immediately pressing health needs could not be met. It was at this point where Dr. Hans Merensky became aware of the interesting findings of Miss Riemerschmid. After ascertaining the value that a more complete investigation would have for health and other workers in the Union he volunteered to bear the whole

SOUTH AFRICAN SOLAR RADIATION SURVEY.

cost of a survey extending over a year, it being understood that the Government would then continue to survey for such further period as would be necessary to supply the data required. The present valuable report by Miss Riemerschmid is the direct results of Dr. Merensky's munificence. The work is to continue for a further five years with the costly instruments purchased by Dr. Merensky for Miss Riemerschmid's initial survey. Deep gratitude goes out from the many workers on problems of applied biology in South Africa to the man whose generosity made this investigation possible.

E. H. CLUVER,

Formerly Secretary for Public Health.

ACKNOWLEDGMENT.

In order to carry out the investigations of the Solar Radiation Survey, 1937/38, the co-operation of a number of interested persons and bodies was secured and in this connection the Department of Public Health is particularly indebted to the following:—

1. Drs. J. Daneel, H. L. Murray and J. Meyer, Rietfontein Hospital.
2. Mr. H. E. Wood, Union Observatory, Johannesburg.
3. Dr. D. H. Pfeiffer and Mr. M. Brennan, Tempe Isolation Hospital, Bloemfontein.
4. Dr. T. S. Paraskevopoulos and Mr. E. Steyn, Boyden Station of Harvard College Observatory, Mazelspoort, Bloemfontein.
5. Dr. H. R. Ackermann, Nelspoort Sanatorium.
6. Dr. J. Jackson and Mr. J. Driver, Royal Observatory, Cape of Good Hope, Cape Town.
7. Dr. D. L. Ferguson and Mr. B. J. Buckley, Health Department, Port Elizabeth Municipality.
8. Mr. S. A. Engelbrecht, Meteorological Office, Durban Aerodrome.
9. Professor H. H. Paine and Mr. M. Roberts, Physics Department of the Witwatersrand University, Johannesburg.
10. Dr. T. E. W. Schumann and Mr. B. R. Schulze, Meteorological Office, Irrigation Department, Pretoria.
11. Mr. H. Coblans, Natal University College, Durban.
12. Messrs. C. M. van Wyk and J. G. van der Wath, Onderstepoort Laboratories.
13. Messrs. W. Zunckel and R. B. Naylor, Natal National Park Hostel.

A. INTRODUCTION.

Tropical and sub-tropical countries where people of European races have come to settle permanently and where animals of European origin have been introduced, present a large number of climatological problems. The climate appears to have many influences, the effects of which can hardly be traced in the white population. Amongst animals, however, particularly in those which carry a high infusion of the blood of European breeds, the difficulty of maintaining themselves successfully in terms of European health and function standards, is apparent. Any investigations likely to improve our knowledge and understanding of these events are of utmost importance, particularly in a country like South Africa, where a possible detrimental influence of the climate is fully realized.

It has long been known, that solar radiation is one of the most potent of all climatic forces affecting organic life. Relatively little research work has as yet been done regarding the influence of solar radiation on human, plant and animal life and function, except in respect of the therapeutic value of the sun's rays in combating human diseases such as tuberculosis, rickets and others. South Africa, however, offers a great variety of problems connected with its abundant sunshine, which can only be studied on the basis of accurate physical measurements of this energy.

Dr. H. Merensky, who realized that the collection of such data on a large scale alone could help to solve many of these problems, decided to sponsor a Solar Radiation Survey in the Union of South Africa, for which he gave a generous grant to the Public Health Department. The grant of £5,000 provided the necessary instruments, staff salaries, travelling and incidental expenses for the period 1937/38.

The work of carrying out the Survey was entrusted to the author. Dr. J. Grober, Professor of Clinical Medicine at Jena University, who is recognised as an authority on acclimatisation, came to the Union to give his advice in respect to the planning of the Survey.

The measurements were carried out at six stations in the Union during the period from July 1937 to June 1938. Whereas in European countries climatic and meteorological conditions vary within small areas, the climate of South Africa is fairly even over large tracts and hence it was possible to survey the solar radiation throughout the country using comparatively few stations.

The results obtained at the six Solar Radiation Stations in the Union during the Survey 1937/38 are discussed in detail in this report.

B. THE AIM OF THE SURVEY.

To study the influence of solar radiation upon organic life a knowledge of the prevailing radiation conditions is a fundamental requirement. Such a foundation includes a knowledge of the exact amounts of radiation originating from the sun which reach the earth at various places and at various times of the day and year, of the variation in quality of the rays and of the quantities of specific bands of the solar spectrum.

The Solar Radiation Survey, 1937/38, adopted the collection of such data as its *first aim*, and the account given below presents the results of certain physical measurements taken during this period at six stations in the Union.

The *second aim* was to correlate and co-ordinate the solar radiation data with meteorological and climatological factors as far as they influence bionomics. This aim may be summed up in terms of a bioclimatological research. Data pertaining to such a research in the Union were also collected during the 1937/38 survey. They consisted of cooling temperature readings and qualitative measurements of the solar radiation.

The *third aim* of the survey follows from the first two indicated above. It is to determine as accurately as possible, in quantity and quality, the physical energy necessary to cause certain biological reactions.

These three aims follow from various biological problems, examples of which may briefly be indicated here: —

1. *Medical*.—Suppose, for instance, a sanatorium or health resort is planned. The results of the bioclimatological survey could be used to determine a suitable area in which to erect the building and they would, together with meteorological data, indicate the climatic conditions to which the inmates would be exposed. Again, if it is necessary to expose a patient to sunlight, the doctor in charge should be guided by the readings of the intensity and quality of the sunlight in order to prescribe the correct dosage.

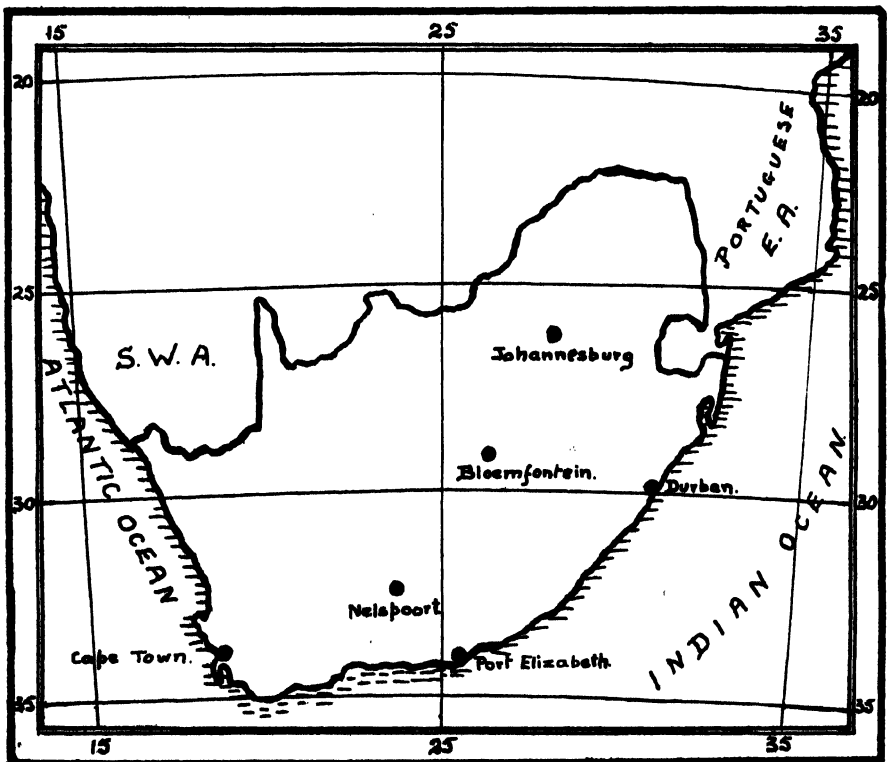
2. *Veterinary*.—Most domestic animals are inclined to seek shade during day-time. The question whether they do this because of excessive solar radiation and whether any adverse effect of the radiation can be prevented to a certain extent by providing shade, is worthy of study. A thorough knowledge of South African sunlight—whether it is stronger than or different in quality from the radiation experienced in the country of origin of the exogenous breeds—is essential for this kind of research. Closely allied to this will be the measurement of bioclimatological factors in areas of the Union where the detrimental influence of environment on livestock is marked and comparing them with measurements from other areas where deterioration is not apparent. Further, to indicate the scope of the work undertaken, one of the many problems connected with the third aim of the survey may be cited i.e. the correlation of physical energies with certain resulting biological reactions. The determination of solar radiation which causes lesions in the skin of sheep infected with the disease known as “geeldikkop” form the basis on which to study and possibly find a remedy for this serious disease.

3. *Botanical*.—It is quite evident that botanical science also offers many interesting problems connected with bioclimatological research. The mechanism of photosynthesis, the conservation of water, date and abundance of flowering, foliar shooting and ripening and many other functions are widely influenced by the total radiation impinging upon plants. A knowledge of this energy, its reduction by the cover of vegetation etc. is of prime importance for botanical research.

The above problems together with many others entail the investigations of every aspect of the bioclimate simultaneously with biological experiments. However, it must be admitted that the methods of measuring the "bioclimate" are not yet so far developed as to enable us to determine every factor which may cause a physiological reaction. Another difficulty is to separate the various components of both the bioclimate and of the physiological reaction. One reaction may result from a number of bioclimatological factors and *vice versa*. Nevertheless it seems vital to determine and correlate as many of these bioclimatological quantities as are possible with the available methods, particularly in a country like South Africa with its abundant sunshine.

It is obvious that the greatest value of any bioclimatological research can be achieved only by close collaboration between the bioclimatologist and the biologist, since they will help to avoid any faulty interpretation of each other's results.

As mentioned before, the Solar Radiation Survey, 1937/38, concentrated more particularly on collecting fundamental data in order to obtain a knowledge of the prevailing radiation and bioclimatological conditions in various areas of the Union.



Sketch Map of the Union of South Africa showing the Six Solar Radiation Stations.

The chapter which follows deals with the significance and purpose of the measurements carried out, and demonstrates how they have been used during the Survey 1937/38 for research work in collaboration with scientific institutions. This is followed by a chapter on the technique of the measurements. Finally the results of the radiation and cooling temperature measurements are presented separately and compared with overseas data.

G. MEASUREMENTS CARRIED OUT DURING THE PERIOD JULY, 1937, TO JUNE, 1938, AND THEIR SIGNIFICANCE.

The Secretary for Public Health, Dr. E. H. Cluver, in close collaboration with Dr. J. Grober of Jena University, decided which areas in the Union would be of greatest interest from a bioclimatological and a public health point of view. The observation stations were erected at Government hospitals within these areas, wherever convenient arrangements could be made. If circumstances were unfavourable more suitable sites were chosen at other institutions.

During May and June, 1937, the six stations were established at the following centres:

- | | | |
|------------------|---|---|
| Inland Stations | { | I. Johannesburg, Rietfontein Hospital. |
| | | II. Bloemfontein, Tempe Isolation Hospital. |
| | | III. Nelspoort Sanatorium (Karoo). |
| Coastal Stations | { | IV. Durban, Aerodrome. |
| | | V. Port Elizabeth, Lady Donkin Isolation Hospital |
| | | VI. Cape Town, Royal Observatory. |

(See sketch map on page 347.)

In order to secure simultaneous readings from these six stations without having specially trained observers, self-registering instruments were used.

From July 1st, 1937, the self-recording instruments were in operation at the six Solar Radiation Stations. Apart from some unavoidable interruptions they registered continuously until June 30th, 1938 and after the completion of the survey the instruments were carefully checked to make sure that their sensitivity had not changed.

In accordance with the threefold aim of the survey it was decided that the following measurements would best serve the purposes of such a survey in South Africa:—

1. Measurements to ascertain the quantity of the total solar energy impinging at various places in the Union.
2. Measurements of the quality of the sun's rays, particularly of the biologically effective ultraviolet radiation.
3. Measurements of the cooling temperature conditions in the various climatic areas.
4. Specific measurements for the purposes of biological experiments in medicine, veterinary science and botany.

1. MEASUREMENTS TO ASCERTAIN THE QUANTITY OF THE TOTAL SOLAR ENERGY IMPINGING AT VARIOUS PLACES IN THE UNION.

(a) *The daily, monthly and yearly amount of sun and sky radiation.*

The total solar radiation emitted from the sun is reduced on its way through the atmosphere. This reduction depends on the geographical situation of a given place, on its altitude above sea-level and on the cloudiness and the turbidity of the atmosphere.

The comparison of the intensity on various days, the mean values for the various months and the fluctuations from these mean values are important in assessing the biological values of the climate in different parts of the Union.

The total solar energy impinging on a horizontal surface was therefore measured at the six Solar Radiation Stations. Hereafter this intensity is called the "*total amount of sun and sky radiation*" as it is composed of the direct sunlight plus the scattered radiation from the sky.

Cloudiness and turbidity vary with the meteorological conditions. An extremely cloudy month will show a relatively small amount of solar energy which does not necessarily correspond with the amount prevailing during the same month in *other* years. It is therefore necessary to eliminate these contingencies by collecting the data over a period of many years to ascertain what amount of energy is normally active in the various climatic and geographical areas of the Union.

(b) *The Intensity of Sun and Sky Radiation at a Given Time.*

Besides the total amount of sun and sky radiation it is important to determine *the intensity of the solar radiation at a given time*. If, for instance, a doctor intends to expose a patient to solar radiation he has to consider its intensity because local meteorological conditions influence this intensity from day to day. It is essential to *measure* it and to estimate the dose of this physical energy just as accurately as the chemical constituents of any medicine are estimated and prescribed.

The graphs on which the total amount of sun and sky radiation is registered make it possible to read the intensity of the solar radiation at any given moment and enable the doctor to determine the correct dose to which he must expose his patient.

2. MEASUREMENTS OF THE QUALITY OF SOLAR RADIATION.

(a) *The red and yellow part of the spectrum.*

The quality of the solar radiation is of importance because the *effect* of any given amount of radiation depends on the quality. An analysis of the sun's light can be achieved by utilizing various filters which permit only light of certain wavelengths to pass. In this way the percentage of red, yellow and other visible rays in the total solar spectrum may be determined.

(b) The Ultraviolet Solar Radiation.

Of all solar rays which reach the surface of the earth, the ultraviolet rays are of great interest as it has been proved by experiments that various specific biological reactions are due to these rays. The most important of these effects are, the bactericidal effect, the changing of ergosterol in the human skin into vitamin D, the erythema effect, the pigmenting effect and the stimulating influence on the metabolism. It is essential in any biological research with which radiation investigations are correlated to estimate accurately the ultraviolet component of the sunshine. Such investigations can either be used in trying to prevent the harmful influence of excessive ultraviolet light (e.g. sunbathing) or they can also be applied by utilizing the beneficial effects of the sunlight for the treatment of diseases.

Comparing South African conditions with those of Switzerland there are two outstanding factors which enhance the climate at the famous health resort in Switzerland. Firstly, there is the altitude above sea-level. In this respect very large areas in the Union have an altitude similar to Davos (Switzerland), which is situated 4,680 feet above sea-level. Secondly, there is the relatively clear atmosphere, which allows a greater amount of ultraviolet radiation to penetrate. It is very interesting to know, therefore, how the intensity of the ultraviolet radiation in South Africa compares with that in Switzerland. This question was made the subject of specific investigations carried out in collaboration with the Solar Radiation Survey 1937/38. There can be no doubt about the importance of such measurements from the public health point of view in fostering the *correct* use of the abundant South African sunshine for the benefit of the population. Equally important is the use of the data of ultraviolet light intensity for biological research on animals and plants.

It may be mentioned here that not only the ultraviolet *solar* radiation, but also the ultraviolet light from the *sky* must be taken into consideration, because the latter is sometimes far in excess of the ultraviolet radiation of the sun alone. Knowing this, a doctor can often eliminate the harmful influence of heat which a patient would get in direct sunlight by exposing him only to the scattered ultraviolet radiation from the sky.

It is quite obvious that only controlled application of ultraviolet light can improve our knowledge of the harmful or beneficial influence of this energy. Readings of the *ultraviolet sun and sky radiation* should therefore always be taken at the time of exposure of patients in order to estimate the proper therapeutic dose at that given time. Careful dosage is particularly important, as an overdose of ultraviolet radiation can result in acute harm.

3. MEASUREMENTS OF THE COOLING TEMPERATURE.

Apart from the radiation there are other factors influencing the living organism when exposed to the "climate", namely air temperature and wind. These two factors are most important, as

they are always present and cannot be eliminated during exposure to the sunlight. They have therefore to be taken into consideration when studying the effect of the bioclimate on living matter. It is, however, very difficult to estimate the combined influence of radiation, wind and air temperature because measurements of that kind depend entirely on the physical qualities of the absorbing body. A hairy coat of an animal, for instance, is quite different in its physical make-up from the smooth skin of a naked human body and will therefore react in a different way to the same physical influences. Consequently the qualities of the measuring instrument, designed to measure a living body's reactions to climatic conditions must be as similar as possible to the physical qualities of the living organism in order that both may react in the same way.

This problem has so far only been solved in the case of the human body. Doctors in Switzerland and Germany, realising the importance of the combined influences of radiation, wind and air temperature, carried out exhaustive studies which resulted in the development of an instrument, the so-called "cooling ball" which represents the human body. The surface temperature of the ball varies according to the cooling or heating effect of the climate and is (within certain limits) equal to the mean skin temperature of the human body. The cooling temperature therefore is a measure indicating the strain of atmospheric conditions on the resting naked human organism. The relationship between physiological strain and cooling temperature was thoroughly studied and the stresses and strains on the heat regulating mechanism of the human body determined. It was found that the least physiological strain occurs at a cooling temperature of 37°C . If the cooling temperature is less than 37° the strain increases because the body is forced to restrict its skin circulation together with the "perspiratio insensibili" and to increase the oxidation. When the cooling temperature is more than 37° , then the body is exposed to stress by overheating. This is, however, automatically controlled by increased perspiration.

It is obvious that the main *practical* value of cooling temperature readings is the correct use of climatic forces in the treatment of human beings. The successful application was proved in one of the children's hospital for surgical tuberculosis on the coast of the North Sea. The dosage of exposure for every one of the 200 children is given strictly according to the readings of the cooling temperature and measurements of the ultraviolet solar radiation. In this way the therapeutic value of the climate was utilized to the utmost.

There is, however, another significance of the cooling temperature readings. It is evident and has to be emphasized over and over again, that the readings cannot be applied to any other living organism except the human being. On the other hand cooling temperature data are for the time being the only "units" which are based on physiological considerations. Bearing in mind, that they represent the physiological conditions of a human organism, the data collected in various areas have a distinct bioclimatological significance in so far as they give well-defined, comparable figures of the combined climatic influences of radiation, air temperature and wind. In this respect they are more closely connected with the

actual climatic influences on any living organism than any one of the meteorological data. The variation of the cooling temperature from hour to hour, from day to day and season to season represents a very important physiological factor of the climate.

The cooling temperature was registered continuously at the six Solar Radiation Station in the Union. As the readings taken were not at the time supposed to be used for practical purposes of dosage, the balls were erected at open sites next to the radiation instruments.

4. MEASUREMENTS FOR THE PURPOSE OF BIOLOGICAL RESEARCH.

In addition to the survey of the solar radiation and the cooling temperature throughout the country, the study of problems connected with solar radiation was taken up in collaboration with various Institutions in the Union, the results of which are published separately. It may be of interest, however, to indicate which problems have been investigated in order to show how the measurements of the Solar Radiation Survey 1937/38 have been used for practical purposes.

(a) *Stellenbosch, Physics Department of the University.*

Dr. G. D. B. de Villiers investigated the climate of Stellenbosch with special reference to delayed foliation of deciduous fruit trees. Previous investigations had suggested that certain injuries on peach twigs were possibly due to light. Dr. de Villiers therefore concentrated on measuring the ultraviolet intensity of solar radiation to find out whether the ultraviolet was responsible for this injury.

(b) *Frankenwald, Ecological Research Station of the Witwatersrand University.*

Miss Margaret Matheson, M.Sc., took readings of the total amount of sun and sky radiation in the open and under cover of grass. At the same time the temperature of the soil at different depths was measured to study the influence of grass on soil temperature and light intensity.

(c) *Rietfontein Hospital near Johannesburg.*

Mr. S. J. Richards, M.Sc., working under the supervision of Professor Paine, Department of Physics of the Witwatersrand University, took measurements of the extreme ultraviolet solar radiation. His investigations give us information on the total intensity of ultraviolet radiation and its variation during the different seasons; they also show how this total intensity is composed of sun and sky radiation and how the relation of both varies with the days and the seasons. Furthermore the results obtained were compared with those obtained in various parts of the world.

(d) *Onderstepoort Veterinary Research Institute.*

Investigation of a serious disease in sheep, Geeldikkop, had shown that the skin of white sheep became photosensitive under the influence of plant poisoning. When such poisoned sheep were kept in a dark stable they remained unaffected, but as soon as they were exposed to the sun's rays, serious lesions, obviously caused by the solar radiation, were noticed.

Measurements of the quality and intensity of the different parts of the solar spectrum were carried out at the same time as photosensitised sheep were exposed for experimental purposes. It was expected that the exposure of the sheep's skin under various filters would help in the determination of the wave-lengths of the harmful rays and thereby assist in finding methods for the protection of the sheep against these rays. It is obvious that this type of investigation is of economic value to the farmers in the areas concerned.

D. THE INSTRUMENTS AND THE TECHNIQUE OF THE MEASUREMENTS.

It is necessary to give a short description of the various instruments used and of the physical methods employed in the collection of the data given in this report. Reference will also be made to the instruments used for direct observations on the ultraviolet light at Stellenbosch and Rietfontein.

1. *Pyranometers and Solarimeters for Measuring the Total Amount of Sun and Sky Radiation.*

The total amount of sun and sky radiation was measured with three pyranometers and three solarimeters.

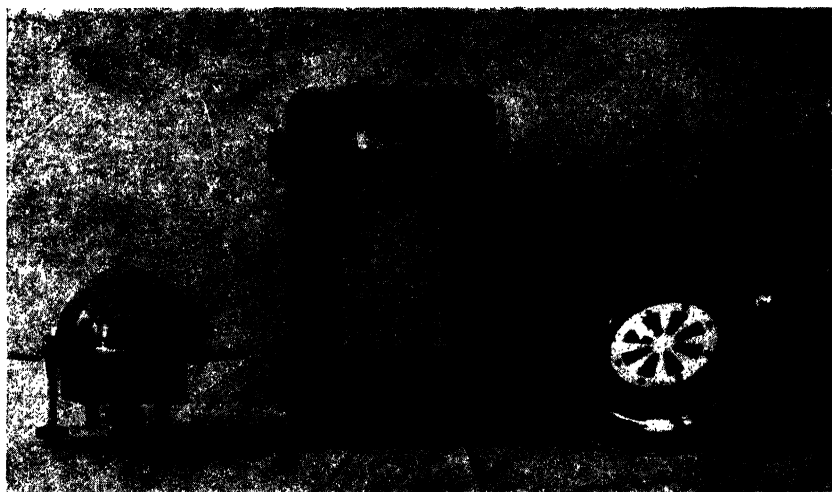


Fig. 1.—Pyranometers and a self-recording Galvanometer.

Pyranometers.—The physical principle on which these instruments work is, that if two wires of different metals are joined to complete a circuit and if one junction is raised to a higher temperature than the other, an electric current flows in the circuit. The strength of this current is proportional to the temperature difference of the two junctions.

The surface of the pyranometer contains several such junctions, an arrangement which is called a thermopile. The alternate junctions are covered with a dull black and a white powder. The black parts absorb the radiation energy and become heated up; the white spots reflect it and remain cool. The difference in temperature of the black and the white parts of the surface of the pyranometer produces an electrical current proportional to the amount of radiation. This current is registered on a graph by a self-recording galvanometer. This instrument is calibrated in such a way that the readings on the graph indicates directly the calories impinging during one minute on one square centimetre of a horizontal surface.

Solarimeters.—The principle on which the solarimeters work is practically the same as that of the pyranometers. The only difference is that, in the case of the solarimeters, only the so-called hot junctions are exposed to the sunlight, and the cold junctions are covered and kept at air temperature. The current produced in the solarimeter is also proportional to the light intensity and the readings on the graph give calories per square centimetre per minute.

The thermopiles in both instruments are exposed horizontally to the sun and sky radiation. They are left in the open continuously and are protected against rain by glass hemispheres.

The pyranometers and solarimeters are connected up with the self-recording instruments by waterproof cables. The galvanometers have to be protected against weather conditions and are therefore kept in a house. The length of the cables permits the radiation instruments to be erected at some distance from the house. The instruments are very reliable when kept in good order, and require about ten minutes attention every day. The accuracy of the readings is within the limit of error of 10 per cent. at the utmost.

The main advantage of using pyranometers or solarimeters in connection with a self-recording galvanometer is the collecting of continuous readings. Although these readings do not indicate the *quality* of sun and sky radiation, they provide the fundamental data for a bio-climatological survey, i.e., the total *quantity* of sun and sky radiation. This intensity is registered on a graph every minute. The mean value of sixty readings gives the average amount of radiation during one hour. From these hourly averages the total daily, monthly and yearly amounts are calculated. In all, 700,000 figures were dealt with during the survey 1937/38.

2. The "Panzer Actinometer" and the "Michelson Actinometer" for Measuring the Total Energy and Energies of Various Spectral Regions of the Solar Radiation.

The Panzer Actinometer is also provided with a thermopile and works on the same principle as the Solarimeter. The main difference is, that with the Actinometer the thermopile is fixed at the bottom of a brass tube which is directed towards the sun and which allows only the direct rays from the sun to strike the thermopile. Attached

to the tube is an arrangement whereby different filters can be put in front of the thermopile. These filters enable the intensities of the solar rays in different regions of the spectrum to be measured.



Fig. 2.--The "Panzer Actinometer".

The filters used were the so-called "Potsdam Normal Filters" which are officially recognised by the "Comité International de la Lumière". During the Solar Radiation Survey of 1937/38 two filters were used, namely the filter "RG 2" and "OG 1". The former measures the red part of the radiation down to the wave-length $623\text{ m}\mu$, and the latter measures the red and the yellow part of the spectrum down to the wave-length $524\text{ m}\mu$. By means of these readings it is possible to determine the percentage intensity of red and yellow rays in the total amount of solar radiation obtained.

The Panzer Actinometer is a very reliable instrument. Its limit of error is 1-2 per cent. For field work the Panzer Actinometer is connected to a portable galvanometer and shows the correct readings about twenty seconds after being exposed to the sun. The readings of the galvanometer are converted into calories by means of a factor which depends on the temperature of the instrument. As it only takes about two minutes to take a reading and work out the result, this instrument could be used for fieldwork in which the intensity of the solar radiation is needed at any given moment.

The "Michelson-Büttner" Actinometer also measures the intensity of the direct total sunlight and of the various parts of the spectrum.

The principle on which the Michelson Actinometer is based is the following:—The sunlight acts on a bimetallic strip consisting of two different metals, fixed rigidly together. The two metals have different coefficients of expansion and if exposed to the sun's rays the strips will bend. The curvature is proportional to the sunlight intensity impinging on the surface of the strips. This curvature is

observed through a microscope with a transparent scale. The readings can be converted into calories per square centimetre per minute by means of a temperature factor.

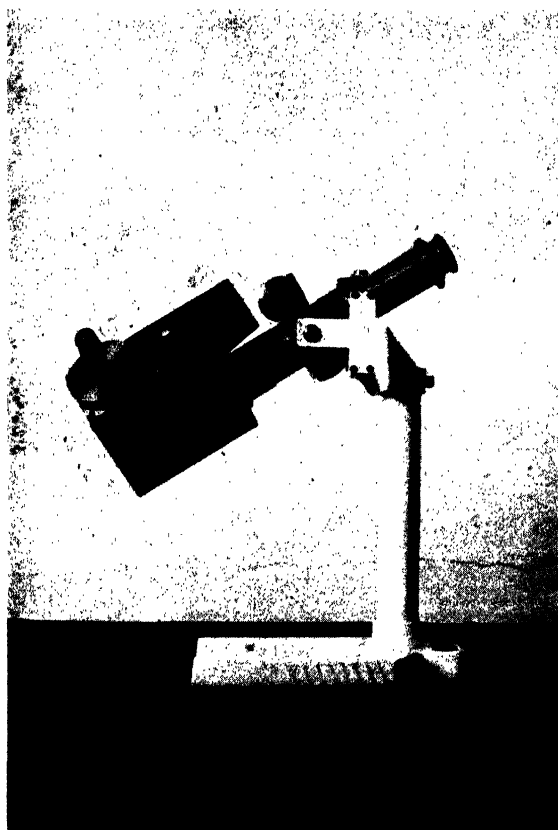


Fig. 3.—The " Michelson Actinometer ".

The Michelson Actinometer is not quite as accurate as the Panzer Actinometer. It is however very suitable for fieldwork, as it consists of a single instrument without appendages and can be used without a table or stand. Its greatest disadvantage is that it is difficult to read under windy conditions. This instrument can also be used with filters.

3. The " Ultraviolet Dosimeter " for Measuring the Ultraviolet Radiation.

The sensitivity of the ultraviolet dosimeter to the various rays of the sun's light is similar to that of the human skin. Measurements with the ultraviolet dosimeter are therefore particularly valuable for estimating dosage in heliotherapy. The readings obtained represent the erythema value of the solar radiation.

The ultraviolet dosimeter works on a colorimetric principle. A chemical solution, which is contained in a quartz tube, is exposed for 1-3 minutes to solar radiation. Under the influence of the ultraviolet light, this solution changes its colour from colourless to red. The amount of reddening of the solution is determined by a colour comparison method. The readings are then converted into ultraviolet units by means of a temperature factor. It requires about five minutes for the exposure to solar radiation, reading and working out the result.

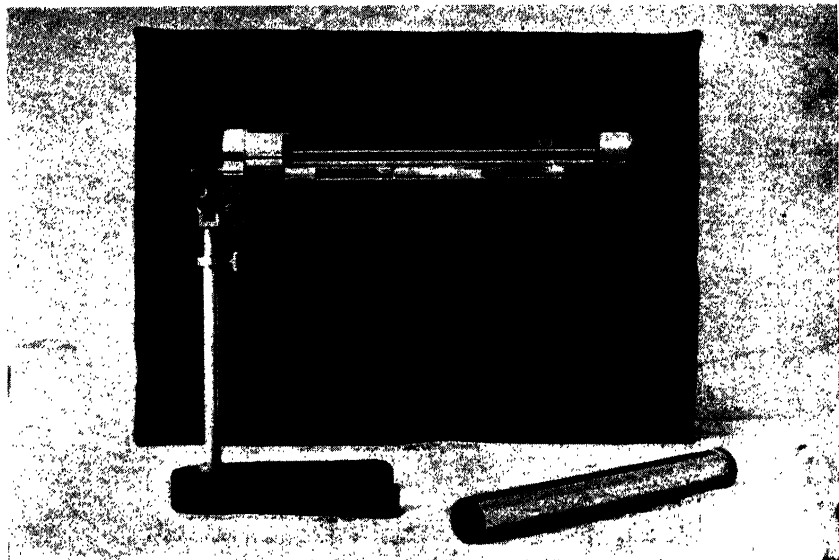


Fig. 4.—The Ultraviolet Dosimeter.

The manufacturers had great difficulty in improving this method to permit the readings to be comparable under different temperature and light conditions. This difficulty has now been overcome.

4. *The Cadmium Cells for Measuring the Short-Wave Ultraviolet Radiation.*

The physical principle underlying the measurement of radiation by means of a cell is the fact that certain metals emit electrons under the influence of light. The number of electrons emitted is proportional to the amount of incident radiation. A one-string electrometer is used for measuring the current produced by these electrons. Cadmium cells are used for measuring the ultraviolet radiation in preference to any others.

As with the ultraviolet dosimeters, the main difficulty with the cells was to create instruments exactly alike in their sensitivity to the various rays of the ultraviolet region of the spectrum. The response of the metallic layer in the cell to the slightest difference

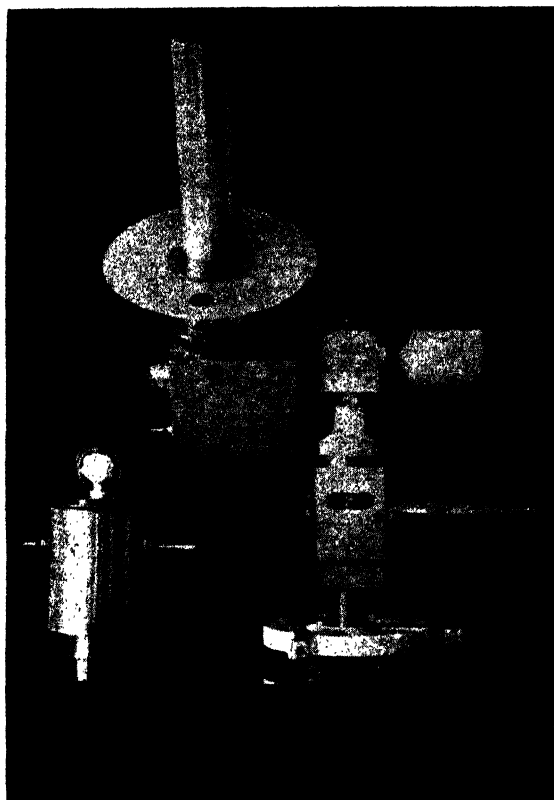


Fig. 5.—Cadmium Cells for measuring the direct ultraviolet solar radiation (connected to the electrometer) and the total ultraviolet sun and sky radiation.

in the spectral composition in the light is great, and only recently has the construction of cadmium cells of equal sensitivity been successfully achieved. Comparative readings hitherto impossible can now be taken with different cells. More details on the method of measurements and the use of the instrument are given by Richards (1939). The method entails rather difficult manipulation and it cannot, therefore, be recommended for general use.

5. *The Cooling Ball for Measuring the Cooling Temperature.*

The cooling ball works on the principle of a resistance thermometer. The resistance of any wire alters with its temperature. This fact makes it possible to measure the temperature by observing the change in the resistance of a wire.

The cooling ball consists of two concentric copper spheres. A thin platinum wire is fixed on the inner surface of the outer copper sphere. The change of resistance of this platinum wire is

proportional to the change in temperature of the surface of the ball. This surface is, however, influenced by the outdoor conditions, by air temperature, wind and radiation. The cooling temperature readings therefore represent the surface temperature of the ball under the influence of outdoor conditions.

A constant electric current passes through a heating element inside the inner sphere to give off a constant amount of heat which is equivalent to the heat produced in a resting human body. This heat keeps the surface temperature of the cooling ball at approximately the same level as the average temperature of the skin of the naked human body, when both are exposed to the same conditions

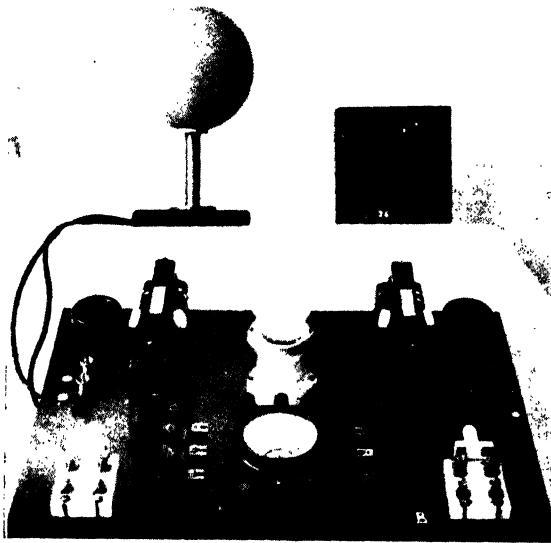


Fig. 6.—Cooling Ball with switchboard and bridge box.

The readings of the cooling ball are registered on the same self-recording galvanometer which is used for the radiation measurements. For this purpose the galvanometer is provided with two independent circuits. The cooling temperature is registered every minute in between the radiation readings. The surface temperature of the ball is given in degrees Centigrade. The graphs are worked out by reading a mean value of the cooling temperature for each hour.

In Fig. 1 (page 353) one of the graphs with solar radiation intensity and cooling temperature tracings can be seen inside the self-recording galvanometer. The graph shows the readings recorded on a clear afternoon. The left line presents the intensity of sun and sky radiation from noon (bottom of the graph) until after sunset, the right line shows the cooling temperature measurements for the same period.

E. RESULTS OF THE RADIATION MEASUREMENTS.**1. *The Radiation at Johannesburg.*****(a) *General Remarks.***

The geographical situation of the Solar Radiation Station at Rietfontein Hospital near Johannesburg is $28^{\circ} 04'$ E. longitude and $26^{\circ} 12'$ S. latitude. The instruments of the survey were set up on an open space beyond the tuberculosis ward of the hospital. They were fixed on a pillar 4 feet above the ground. The horizon was, unfortunately, not quite clear. Trees shaded the instruments in the early morning and late afternoon hours during part of the year.

Before referring to the climatic conditions at Johannesburg in particular, it is advisable to give extracts from an article entitled "The Climate of South Africa" by the Chief Meteorologist, appearing in the "Handbook for Farmers in South Africa". This will facilitate the understanding of the climatic events which occur during the seasons. It also clarifies the terminology.

"In summer on account of the intense heating of the land, a more or less permanent low pressure is established over the centre of South Africa.—During the passage of a high-pressure system along the coast—there is a flow of air from the high pressure towards the low pressure, i.e., from the sea on to the land. This air, coming off a warm ocean, is laden with moisture which is precipitated—against the eastern escarpment and mostly in the form of thunderstorm over the interior."

"In winter, conditions are more or less reversed: due to the more rapid cooling of the land mass relative to the surrounding oceans, a permanent high pressure or anticyclone is established over the land which effectually bars any influx of moisture from the sea.—the wind blows off the land towards the sea."

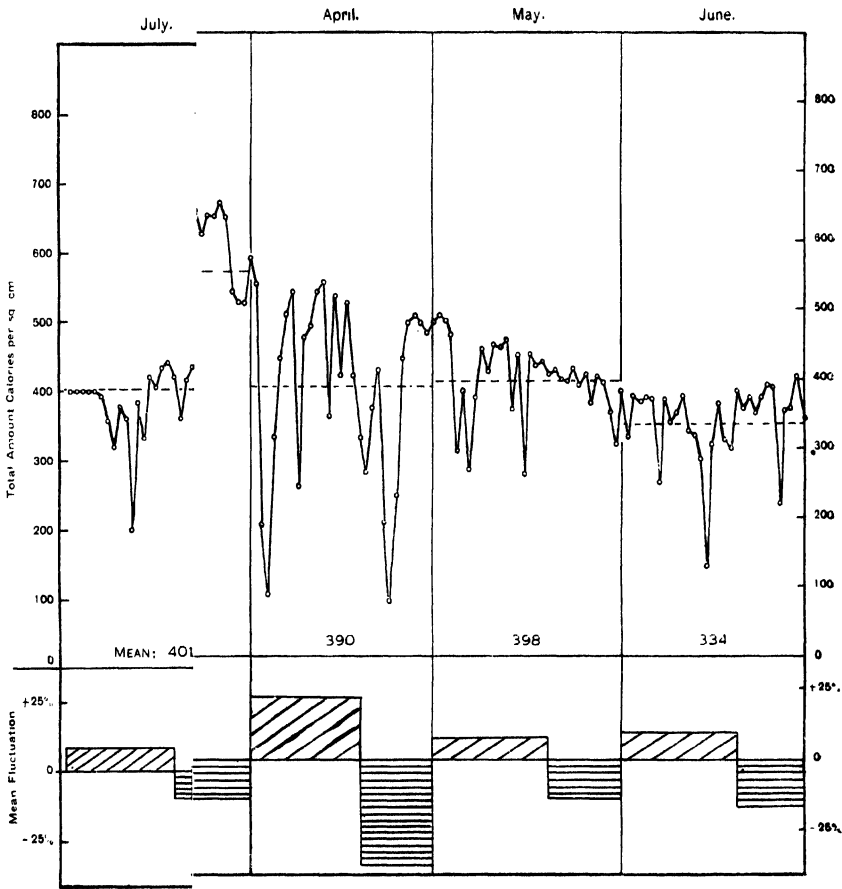
Referring to Johannesburg in particular again, the significant climatic features are:

In *summer*: low atmospheric pressure; prevailing winds northerly; mean air temperature 68° F. (mean of January, February and March); rains, mostly in the form of thunderstorms; mean cloud amount still less than 5/10 of the sky.

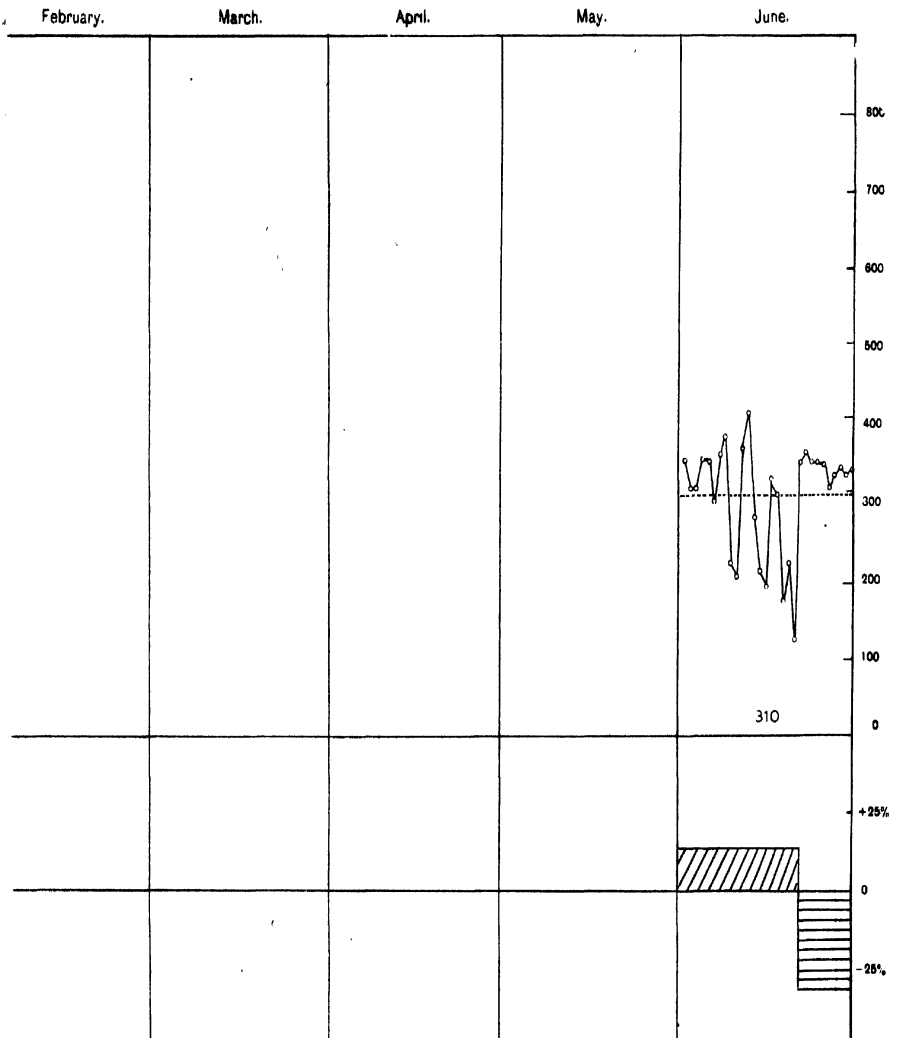
In *winter*: high atmospheric pressure; prevailing winds north-westerly, but almost 40 per cent. of the time calm; mean air temperature 51° F. (mean of June, July and August); very dry atmosphere; very little cloud; at night rapid loss of heat through radiation from the earth to the cloudless sky.

(b) *The Total Amount of Sun and Sky Radiation at Johannesburg.*

The intensity of sun and sky radiation was measured with a pyranometer. Graph I shows the total amount of radiation for every day from July, 1937, until June, 1938. The horizontal dotted lines and the figures in each monthly column indicate the mean values for every month.



tion.
values. Mean
monthly amount



During July and August, 1937, Johannesburg experienced a steady amount of sun and sky radiation. This was due to the typical winter conditions over the interior. The mean total amount was rather low owing to the low angular altitudes of the sun. In September the period of typical winter weather obviously ceased with the commencement of the rainy season. Nevertheless the total amount of radiation increased rather steadily during September, October and November with the increasing altitude of the sun. November in particular showed a long period of dry weather with a great amount of radiation corresponding to large solar altitudes. December, 1937, had excellent rains and frequent cloudy days which reduced the total amount of radiation markedly. This reduction was quite pronounced until February, 1938, and showed the typical influence of the rainy season. Very frequent cloudy weather over the interior was the main cause of the comparatively small amount of radiation in April. In May and June, 1938, the clear winter weather was very pronounced and again a very steady amount of radiation resulted.

Although the *mean* values for each month are rather significant, it is necessary to consider the fluctuations about these mean values. Radiation far removed from the monthly mean may be more important for the biological events than the mean amount itself. It is analogous to the deviation of the actual monthly rainfall from the mean monthly precipitation.

The graphs of the total amount of sun and sky radiation, therefore, show the number of days on which the fluctuation of the amount of radiation was above (positive) or below (negative) the mean value for the month. It shows this positive and negative amount of fluctuation expressed as a percentage of the mean monthly amount of sun and sky radiation.

In Johannesburg the fluctuation of the amount of radiation about the mean monthly amount was small in winter but large in summer.

2. *The Radiation at Bloemfontein.*

(a) *General Remarks.*

The Solar Radiation Station was established at Tempe Isolation Hospital, about 5 miles west of Bloemfontein (Long. $20^{\circ} 13' E.$, Lat. $29^{\circ} 07' S.$, 4,500 feet above sea-level).

The significant features of the climate at Bloemfontein are rather similar to those prevailing at Johannesburg (see page 360). They are both situated in the climatic zone of the highveld, a plateau at 4,000 to 6,000 feet above sea-level comprising the northern part of the Cape Province, the Orange Free State and major portions of the Transvaal. On the whole Bloemfontein is appreciably drier than Johannesburg, the annual rainfalls being $20''$ and $30''$ respectively. The mean air temperature for summer is $72^{\circ} F.$, for winter $48^{\circ} F.$

The instruments were erected on an open space near the nurses' home. They were set up on a pillar 4 feet above the ground. Unfortunately one of the instruments broke down in December and could not be repaired until May as spare parts had to be ordered from Europe. Thus measurements of the total amount of sun and sky radiation were only taken from July until December, 1937. In May, 1938, the instruments were transferred to the Boyden Station Observatory and were registering there the following June.

(b) The Total Amount of Sun and Sky Radiation at Bloemfontein.

As measurements of the total amount of sun and sky radiation are not available for the months January until June, 1938, it is not possible to discuss the main features of the amount of the radiation obtained during the course of the year except for the first six months.

Graph II shows the total amount of sun and sky radiation for every day.

During the period beginning with July and ending with September, fine, cloudless winter weather predominated, resulting in a steadily increasing amount of sun and sky radiation. In October and November, the prevailing influences on the amount of radiation were the altitude of the sun and infrequent cloudy weather, resulting in a further steady increase of intensity. A marked influence on the radiation due to the rainy weather was only noticeable towards the very end of November and during December. This is also shown by the fluctuation from the monthly average amount of sun and sky radiation (see Graph 2).

3. The Radiation at Nelspoort Sanatorium.

(a) General Remarks.

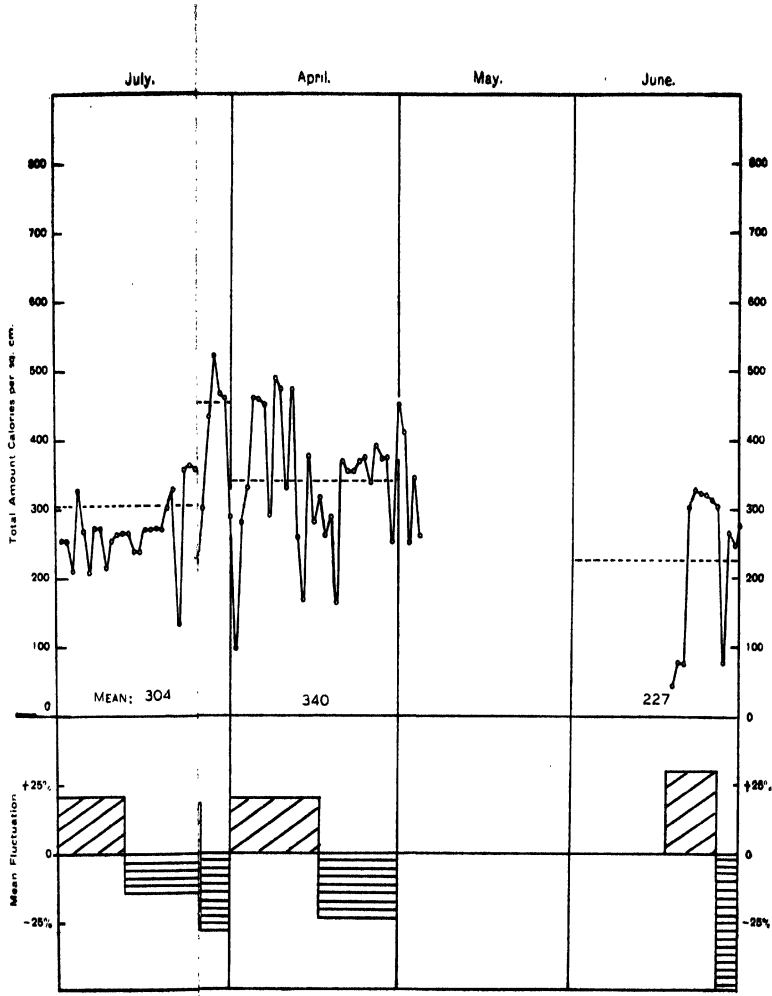
Nelspoort Sanatorium is situated in the Karroo and in spite of being located on the edge of it, its climate is typical of that area (Long. $23^{\circ} 01'$ E., Lat. $32^{\circ} 09'$ S., 3,319 feet above sea-level).

The instruments were fixed on the roof of the new European ward.

The characteristic features of the climate at Nelspoort are the following: For pressure conditions refer to general remarks on Johannesburg (see page 360).

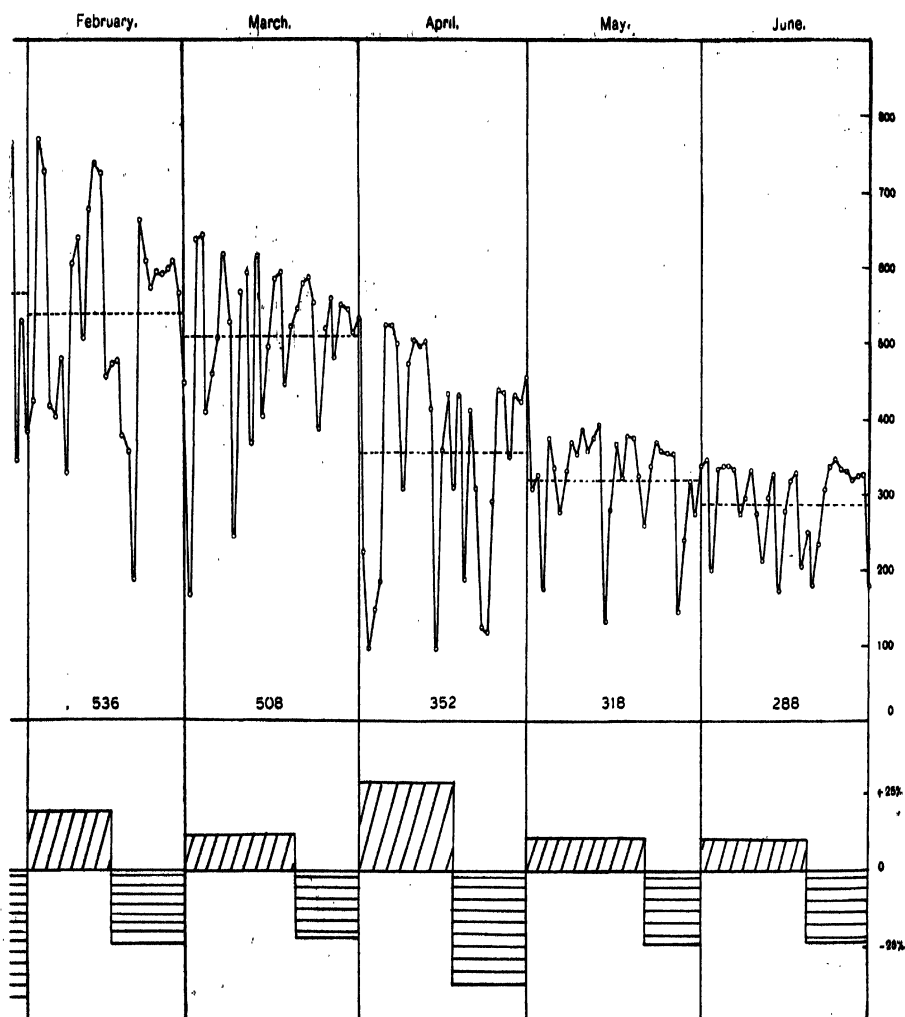
In *summer*: the prevailing wind direction is south-south-east; mean air temperature 73° F. with very marked diurnal fluctuation; low relative humidity; small rainfall and little cloudiness.

In *winter*: prevailing winds from the north to the west sector; mean air temperature 51° F., influenced by the strong incident radiation during daytime and loss of heat through outward radiation at night; extremely dry; almost cloudless skies.



adiation.

Monthly values: Mean
 Mean monthly amount



(b) *The Total Amount of Sun and Sky Radiation at Nelspoort Sanatorium.*

The total amount of sun and sky radiation is given in Graph III.

Except for a few fairly cloudy days a very steady total amount of sun and sky radiation took place from July until the middle of October, producing a very long period of increasing intensity. Then the influence of the rainy season commenced. The three months, November, December and January had an equal mean amount of radiation with many rather cloudy days; but there were also two clear periods of about 7 days each with over 800 calories per square centimetre per day, which is a very large amount. During the following months measurements were only taken periodically and can therefore not be discussed.

4. *The Radiation at Durban.*

(a) *General Remarks.*

The new Tuberculosis Hospital was still under construction and the measurements of the Solar Radiation Survey at Durban were therefore, carried out at the Aerodrome (Long. $31^{\circ} 03' E.$, Lat. $29^{\circ} 52' S.$, 20 feet above sea-level).

The instruments were set up on the roof of the new Aerodrome buildings. The horizon was quite clear except for the Berea ridge shading the instruments shortly before sunset.

The climatic conditions at Durban may be briefly summarised as follows:—

In summer: pressure relatively low; the prevailing winds blow along the coast, either from north-east or from south-west; mean air temperature $75^{\circ} F.$; very humid, the summer being the rainy season; cloud amount usually high especially with south-westerly winds.

In winter: pressure relatively high; winds show a tendency to blow more off the land; mean air temperature $64^{\circ} F.$; humid; still a fair amount of clouds due to proximity to the ocean though much less than in summer.

(b) *The Total Amount of Sun and Sky Radiation at Durban.*

The total amount of sun and sky radiation at Durban is given in Graph IV.

After three months of winter conditions (July, August and September) including several periods of about 10 days when the radiation was practically undisturbed, the beginning of October brought with it the distinct change to summer conditions. The rainy season lasted until February, reducing the radiation considerably. Cloudless days were quite rare. At the end of February there were 8 days of clear weather, followed by another period of decreased sun and sky radiation. This decrease was not as pronounced in

March as in April. Then a change to clear winter weather conditions took place. The amount of radiation was nevertheless not very large because of the low altitude of the sun in winter.

During four winter months, July and August, 1937, and May and June, 1938, the fluctuation from the average monthly amount of sun and sky radiation was small. During the other months the radiation varied considerably from day to day. This fact has to be taken into account as an important factor of the radiation climate at Durban.

5. *The Radiation at Port Elizabeth.*

(a) *General Remarks.*

Port Elizabeth's geographical data are: Long. $25^{\circ} 37'$ E., Lat. $33^{\circ} 37'$ S., 250 feet above sea-level.

The Solar Radiation Station was set up on the grounds of the new Lady Donkin Isolation Hospital. The location of the instruments was not favourable because they were shaded during the early morning and late afternoon by some trees. Nevertheless this place was chosen as it could not be improved upon at any of the other hospitals in that area.

Port Elizabeth, situated on the south coast of the Cape Province, falls in the climatic zone which receives rain in all seasons. Prevailing winds are from the east and west, more or less along the coast; mean air temperature in summer 70° F., in winter 59° F.; in late winter occasionally hot, dry and unpleasant north-westerly winds; cloud amount fairly high throughout the year.

(b) *Total Amount of Sun and Sky Radiation at Port Elizabeth.*

The total amount of sun and sky radiation, as shown in Graph V, demonstrates the influence of the rains occurring in all season. There was no definite period of uninterrupted radiation as at the inland stations with summer rainfall, nor the clear summer season as in Capetown. On the other hand, partly cloudy days with a large amount of radiation occurred frequently for the reason, that the reflection from the clouds increases the total intensity when the sun shines between white clouds.

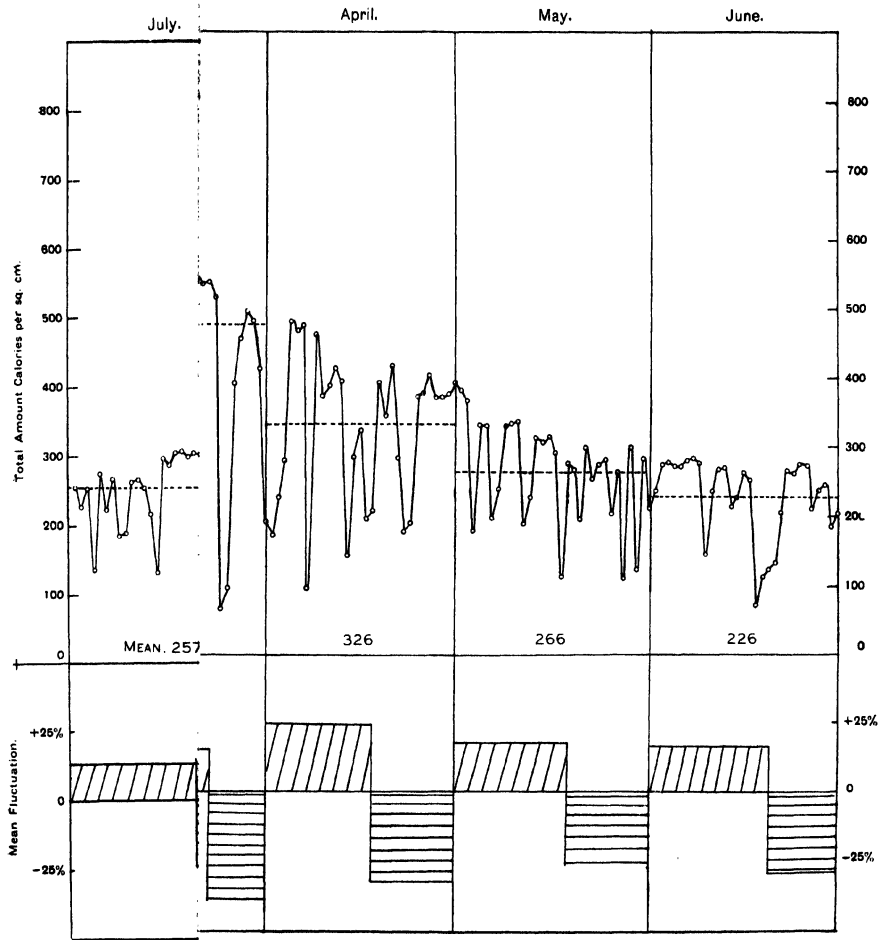
There were large and frequent fluctuations from the mean monthly amounts.

6. *The Radiation at Capetown.*

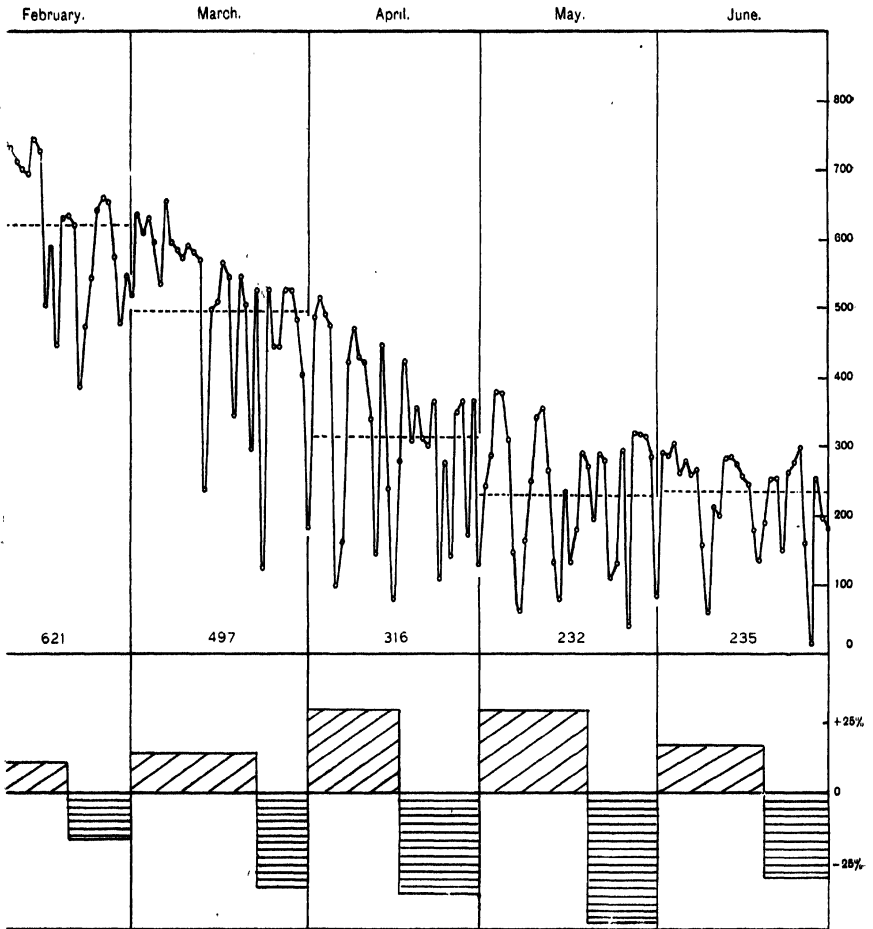
(a) *General Remarks.*

In Capetown the instruments were established at the Royal Observatory (Long. $10^{\circ} 28'$ E., Lat. $33^{\circ} 56'$ S., 40 feet above sea-level).

The instruments were fixed on the roof of the main building, freely exposed to the elements.



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onthly amount



Important for the conditions prevailing at any particular place in Capetown is its position on either the southern, eastern or northern slopes of Table Mountain, because cloudiness and rainfall are strongly influenced thereby. Thus quite a pronounced variation of these elements exists within a limited area.

The main features of the climate of Capetown are those of the winter rainfall area.

In *summer*: fairly dry and clear weather; winds almost exclusively from the south to south-east; mean air temperature 71° F.; cloud amount fairly low during the midsummer months.

In *winter*: prevailing winds from the south-east and north-west, the latter resulting in cloudy and rainy weather; mean air temperature 56° F.; both humidity and cloud amount high; weather frequently unsettled.

(b) *The Total Amount of Sun and Sky Radiation at Capetown.*

The influence of changing weather conditions in Capetown is at once obvious on looking at Graph VI, which shows great variations of the total amount of sun and sky radiation nearly the whole year round. The interruption of fine days by cloudy days reduced the radiation again and again. It is certain that this must be of great importance to biology, particularly to plants, which are exposed to this frequent change of light intensity.

The fluctuation from the monthly mean amount of radiation was very great all the year round.

Another important conclusion which can be drawn from Graph 6 is the fact, that Cape Town was *the* place which received the *greatest monthly amount* of radiation during the period under investigation. This was due to the fact that the dry summer season coincides with the highest altitudes of the sun. A period of more than six weeks (from the 1st of December until the 12th January), interrupted only by a few cloudy days, brought a daily average amount of 797 calories per square centimetre, a remarkably great intensity.

On the other hand, the influence of cloudy weather was sometimes very great. It reduced the total amount of sun and sky radiation considerably, e.g. while 740 calories were registered on one day (12.1.1938), only 110 calories occurred the next.

The significant features of the total amount of sun and sky radiation in Capetown were:—

- (1) A steady increase of the mean total amount with the increase in sun's altitude.
- (2) A period of comparatively many bright days with a great amount of radiation from December until the middle of February.
- (3) Great fluctuations from the mean total amount during the remaining months.

COMPARISON OF THE TOTAL AMOUNT OF SUN AND SKY RADIATION OBTAINED AT SIX STATIONS IN THE UNION.

1. *Comparison of the Monthly Average Amount.*

The amount of radiation impinging on a horizontal surface at any particular place depends mainly on two factors: firstly, on the altitude of the sun, or in other words on the angle of incidence of the rays, and secondly, on the atmospheric disturbances such as the cloudiness, water vapour content, and amount of dust and other particles in the air.

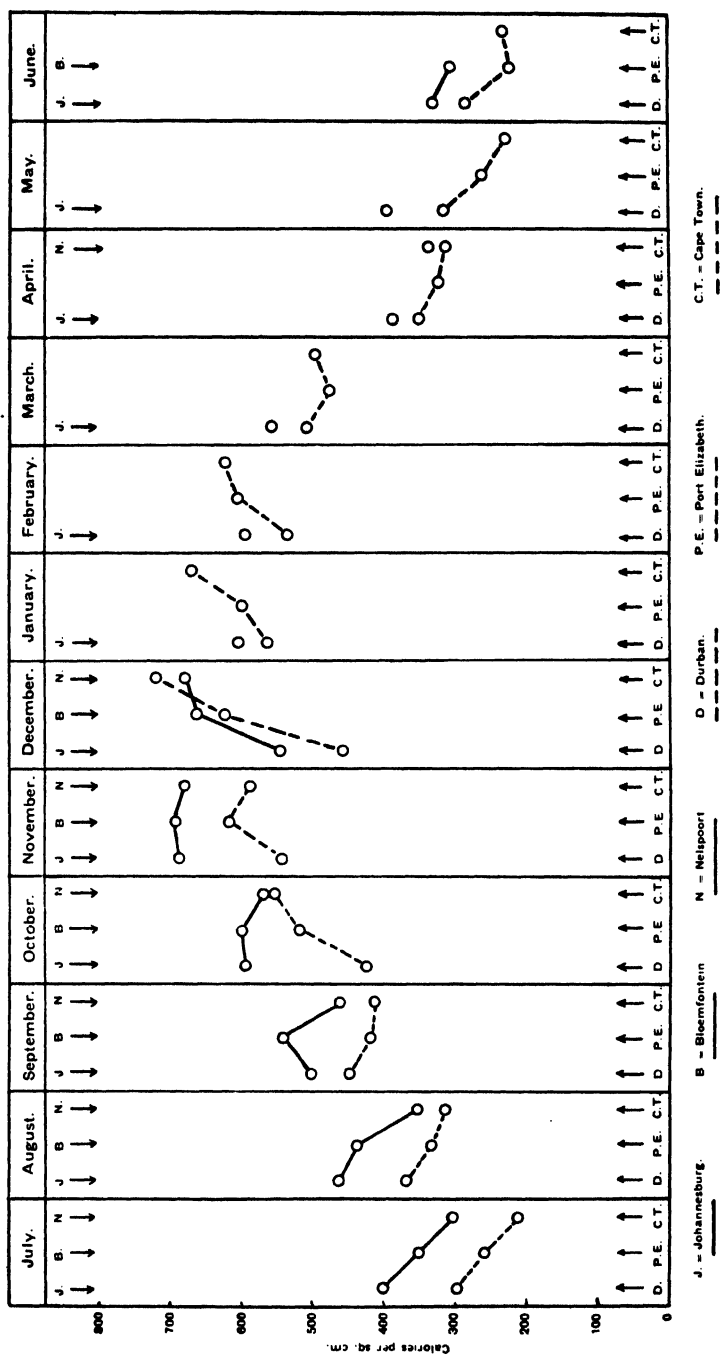
(a) *The Inland Stations.*—Graph VII shows the average monthly amount of sun and sky radiation at the six Solar Radiation Stations in the Union. It indicates that the influence of the sun's altitude was the dominating factor at the inland stations during *the winter months* (July and August 1937 and June 1938). This is proved by the following fact:—

The greatest total amount of radiation during these months was experienced in the most northern station, Johannesburg, where the sun's altitude is greatest. Taking the average amount of radiation for cloudless days only, a comparison of the three inland stations shows, that Johannesburg again received the greatest amount. Next in order was Bloemfontein and then Nelspoort Sanatorium. After August, 1937, the atmospheric disturbances influenced the total amount. Johannesburg no longer experienced more radiation than the other inland stations further south. This refers to the months October and November 1937, when the rainy season was not yet very pronounced. In December and January the sequence of the amount of radiation experienced from the north to the south was opposite to that in winter. Nelspoort had the greatest amount followed by Bloemfontein and then Johannesburg. A comparison for the months February until May, 1938, is unfortunately not possible due to the absence of readings at either Bloemfontein or Nelspoort. In June, 1938, the sequence of the amount of radiation was again from north to south as during the winter months 1937.

(b) *The Coastal Stations.*—Before comparing the results at the the three coastal stations, the following facts have to be emphasized:—

- (1) Cape Town and Port Elizabeth are situated at the same latitude, 34° S., which results in an equal altitude of the sun in both places. Thus, as far as the influence of the sun's altitude is concerned, the total amount of radiation in Cape Town and Port Elizabeth should be equal. Any difference in amount must consequently be due to atmospheric conditions.
- (2) Cape Town is situated in the small area of pronounced winter rainfall; Port Elizabeth experiences rains more or less the whole year round with no distinct rainy season. Durban, situated at 30° S., lies in the area of summer rains.

GRAPH VII.
Monthly Average Amount of Sun and Sky Radiation at Six Stations in the Union.



The results:—

Cape Town and Port Elizabeth experienced a similar amount of radiation all the year round except for two months, namely December and January. During these two months a considerable amount of radiation was recorded at Cape Town where the clear summer season then coincides with the greatest altitudes of the sun. This amount not only exceeded that of Port Elizabeth but was also greater than that at any of the inland stations.

The third coastal station, Durban, had a greater amount of radiation than the other coastal stations from July until September, 1937, and again from March until June, 1938. This applies to the monthly average as well as to the amount obtained on cloudless days. During the rainy season (October until February), however, the reduction of the radiation by clouds was so effective that it could not be compensated for by the greater altitude of the sun in this most northerly coastal station.

(c) *Comparison of the Inland and the Coastal Stations.*—Another interesting comparison is that between the amount of radiation registered at Durban and at Bloemfontein, because both are situated at about the same latitude. The approximately equal altitudes of the sun at both stations result in nearly the same angle of incidence of the sun's rays on a horizontal surface. Differences in the amount of radiation were accordingly due only to atmospheric disturbances, i.e. the differences in atmospheric conditions at sea-level (Durban) and at an altitude of 4,500 feet (Bloemfontein).

As far as readings for Bloemfontein are available, a comparison with the Durban readings shows that the amount of radiation at Bloemfontein was always greater than the amount registered at Durban. This result could be expected because of three factors present at Durban:—

- (1) The greater amount of cloudiness at the coast.
- (2) The reducing influence of smoke and carbon particles in the area of a town and harbour in contrast to clear air conditions at a place like Tempe Isolation Hospital which is situated 5 miles out of Bloemfontein.
- (3) The influence of a thicker layer of atmosphere above the sea as compared with the thinner layer above the highveld.

These points are mentioned here to indicate that there are also minor factors influencing the amount of radiation at any particular place, namely the altitude above sea-level and the local atmospheric conditions.

Referring to Graph VII again there is still another result which can clearly be demonstrated from this graph. *The amount of radiation recorded at the inland stations exceeded the amount at the coastal stations practically all the year round.* This is also shown in Table 1, which gives the monthly total amount of sun and sky radiation for the six stations in the Union.

TABLE 1.

*Monthly Total Amounts of Sun and Sky Radiation
at Six Stations in the Union.*

Month.	Johannes- burg.	Bloem- fontein.	Nelspoort.	Durban.	Port Elizabeth.	Cape Town.
July.....	12,436	10,883	<i>9,609</i>	9,262	7,977	<i>6,614</i>
August.....	14,373	13,536	10,872	11,341	10,330	9,686
September.....	15,052	16,187	13,858	13,409	12,582	12,371
October.....	18,389	18,525	17,633	13,158	16,031	17,105
November.....	20,544	20,691	20,385	16,223	18,451	17,644
December.....	16,897	20,520	20,979	14,186	19,268	22,301
January.....	18,087	—	—	17,451	18,606	20,698
February.....	16,604	—	—	14,999	16,919	17,389
March.....	17,299	—	—	15,733	14,754	15,404
April.....	11,712	—	10,186	10,559	9,769	9,487
May.....	12,324	—	—	9,849	8,236	7,187
June.....	<i>10,008</i>	<i>9,289</i>	—	<i>8,645</i>	6,777	6,945

The figures in this table give the total monthly amounts of radiation in calories impinging on one square centimetre of a horizontal surface. The figures in black indicate the greatest amount for each station, the figures in italics show the smallest amount for each station.

The figures in Table 1 are very instructive. They show the following outstanding features during the course of the year:—

The greatest monthly amount of radiation in the Union was obtained by the following stations:—

During—

July and August, 1937.....	2 months	in Johannesburg.
September, October and November, 1937	3 months	in Bloemfontein.
December, 1937, January and February, 1938.....	3 months	in Cape Town.
March, April, May and June, 1938.....	4 months	in Johannesburg.

This shows that during six months of the year under investigation, Johannesburg of all stations, obtained the greatest amount of radiation. But it is also possible that during some of these six months the amount at Bloemfontein may have been greater. During at least three other months Bloemfontein received the greatest amount of radiation.

The distribution of the monthly maximum amounts of radiation obtained in the Union may be summarised as follows:—

During nine out of twelve months the greatest amount of radiation was obtained in the climatic zone of the highveld. During the remaining three months (December, 1937, January and February, 1938) the greatest amount was recorded in Cape Town.

SOUTH AFRICAN SOLAR RADIATION SURVEY.

The smallest amount of radiation in the Union was obtained at the following stations:—

During—

July, August and September, 1937.....	3 months	in Cape Town.
October, November, December, 1937, January and February, 1938.....	5 months	in Durban.
March, 1938.....	1 month	in Port Elizabeth.
April and May, 1938.....	2 months	in Cape Town.
June, 1938.....	1 month	in Port Elizabeth.

This may be summarized as follows:—

During all the twelve months the smallest amount of radiation was obtained at one or other of the coastal stations. In five of the twelve months Cape Town recorded the least; during five other months Durban received the smallest amount.

It has to be considered, however, that the “greatest” and “smallest” amounts are often not very outstanding, as the differences between the total amounts at the various stations were sometimes relatively small.

After discussing the question *where* the greatest and smallest amounts of radiation were measured during the course of the year it is perhaps relevant to consider *when* these values were obtained at the various stations. The figures in Table 1 show that:—

At each station the greatest amount of radiation occurred during the months November or December, 1937. The smallest amounts were recorded during the months of July, 1937, and June, 1938.

Furthermore it is of interest to compare, at each station, the ratio of the greatest to smallest monthly amount of radiation. These figures are given in Table 2.

TABLE 2.

Differences between the Greatest and the Smallest Monthly Amount of Radiation at Four Stations in the Union.

Name of Station.	Greatest Monthly Amount.	Smallest Monthly Amount.	Ratio.
Johannesburg.....	20,544	10,108	2 : 1
Cape Town.....	22,301	6,614	3 : 4
Port Elizabeth.....	19,268	6,777	2 : 8
Durban.....	17,451	8,645	2 : 0

The ratios are of particular *biological* interest in botanical and veterinary science because they demonstrate the extremes to which plants and animals are exposed while living in the open all the year round. The figures in Table 2 indicate that:—

Johannesburg registered during the month of greatest radiation, twice as much solar energy as it did during the month of lowest radiation. Capetown, Port Elizabeth, and Durban received in the month with maximum radiation respectively 3·4, 2·8 and 2·0 times the amount that was registered during the month with minimum radiation.

Before concluding the discussion on the monthly total amounts of radiation at the six stations in the Union it is of interest to show their distribution over the year on a graph, as given in Graph 8. Referring to the various stations separately the main features of this graph may be summarised as follows:—

The amount of radiation obtained shows, in all six stations, an increase and decrease with the seasons. Johannesburg received a rather irregular amount of radiation during the course of the year. At Bloemfontein and Nelspoort the increase of the monthly amount with the increase of the altitude of the sun was progressive. In Durban great variations of the amount of radiation occurred from month to month. Port Elizabeth showed a very regular distribution over the year. In Capetown the amount also increased and decreased steadily in accordance with the sun's altitude, but showed distinctly high readings in December and January.

2. Comparison of Half-Yearly Total Amounts of Sun and Sky Radiation at the Six Stations in the Union.

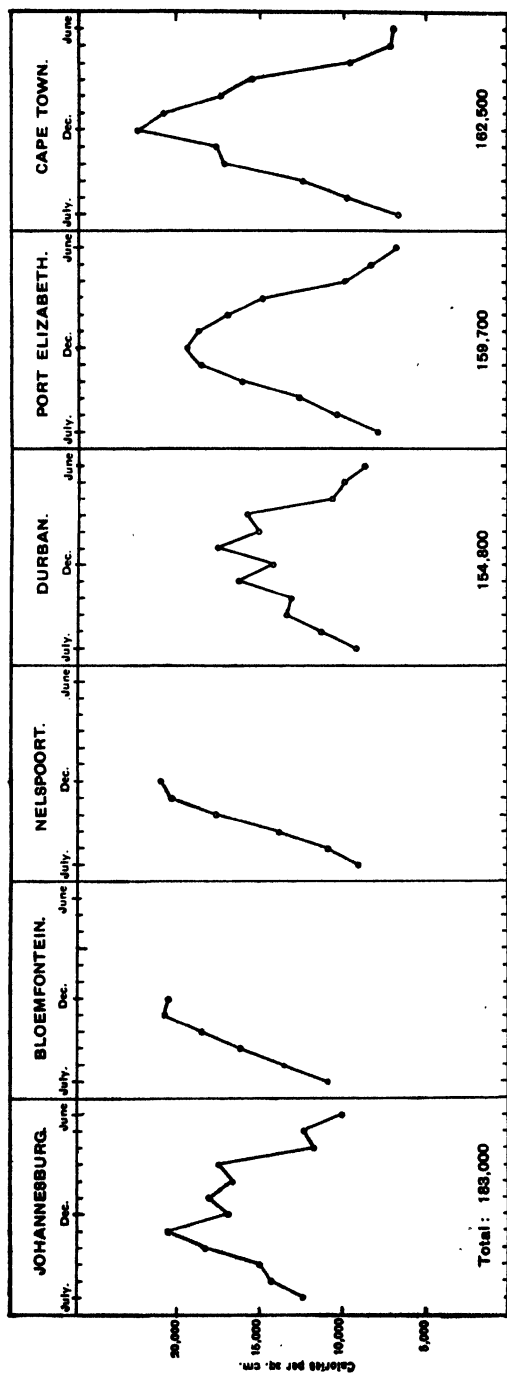
The total amount of sun and sky radiation for all six stations is only available for the first half-year of the Solar Radiation Survey 1937/38. Table 3 gives the figures for July until December, 1937 (first half-year) and for January until June, 1938 (second half-year) separately.

TABLE 3.

Yearly Total Amount of Sun and Sky Radiation at Six Stations in the Union.

	INLAND STATIONS.			COASTAL STATIONS.		
	Johannesburg.	Bloemfontein.	Nelspoort.	Durban.	Port Elizabeth.	Cape Town.
First halfyear.....	97,700	100,300	92,700	77,600	84,600	85,700
Second halfyear...	86,000	—	—	77,200	75,000	77,100
Total for the year.	183,700	—	—	154,800	159,600	162,800

GRAPH VIII.

Monthly *Total* Amounts of Sun and Sky Radiation and their Distribution over the Year.

Summarising Table 3 shows the following:-

During the first half-year under investigation the total amount of sun and sky radiation was largest at Bloemfontein, next in amount was that at Johannesburg and then Nelspoort Sanatorium. At the coast, Capetown and Port Elizabeth had an approximately equal amount of radiation. Durban's amount was distinctly smaller, having received 22 per cent. less radiation than Bloemfontein.

The second half-year showed a greater amount at Johannesburg than at the coastal stations. These experienced a fairly equal amount during the period.

The total for the year was distinctly larger at Johannesburg than at the three coastal stations.

3. Comparison of the Amount of Sun and Sky Radiation at Johannesburg with that at Three Other Places in the World.

In order to give the reader a better general interpretation of the facts and figures given in the foregoing text it will perhaps be of interest to present a comparison of these results with those obtained at places in other parts of the world. The readings from the following places were chosen for this comparison:—

- (1) Johannesburg, South Africa, 5,800 ft., 28° S., readings from July, 1937, to June, 1938.
- (2) Nairobi, Kenya, 6,000 ft., 4° S., readings from December, 1934, to May, 1935.
- (3) Davos, Switzerland, 4,700 ft., 47° N., readings during the years 1920 and 1921.
- (4) Bad Nauheim, Germany, 450 ft., 50° N., readings during the year 1935.

The local conditions of Johannesburg have already been discussed. Nairobi, capital of Kenya, is located on the East African Highlands, about 400 miles from the coast. Davos, the famous health resort in Switzerland, is situated in a wide open mountain valley, and Bad Nauheim, a well known spa in Germany, lies on the north-eastern slopes of the Taunus, a mountain of medium height, and represents an average semi-humid climate at low altitude.

Table 5 gives the monthly average amount of sun and sky radiation for the above-mentioned places.

A comparison of the figures in this table is more significant when considering the conditions mentioned in Table 4.

SOUTH AFRICAN SOLAR RADIATION SURVEY.

TABLE 4.

Place.	1. Range of Sun's Culmination.		2. Altitude Above Sea-level.	3. Yearly Average Number of Hours of Daily Sunshine.
	Highest.	Lowest.		
Nairobi.....	90°	68°	6·000 ft.	6·3 hr.
Johannesburg.....	87°	33°	5·800 ft.	8·7 hr.
Davos.....	67°	20°	4·700 ft.	5·6 hr.
Bad Nauheim.....	62°	16°	450 ft.	3·8 hr.

TABLE 5.

Monthly Average Amount of Sun and Sky Radiation at Johannesburg and Three Other Places in the World.

Month.	SOUTHERN HEMISPHERE.		Month.	NORTHERN HEMISPHERE.	
	Nairobi.	Johannesburg.		Davos.	Bad Nauheim.
July.....	—	401	January....	154	57
August.....		464	February....	307	124
September.....		502	March.....	470	304
October.....	619	593	April.....	528	281
November.....		685	May.....	538	496
December.....		545	June.....	621	527
January.....		665	July.....	640	553
February.....	587	593	August.....	511	433
March.....		558	September..	468	287
April.....		548	October....	358	194
May.....	—	390	November..	191	72
June.....		398	December..	141	53
June.....		334			
Total for the Year.....	—	183,700		150,029	103,380

In winter (Southern and Northern hemisphere) the amount of radiation was much larger at *Johannesburg* than at *Davos* and in the latter again far superior to the amount at *Bad Nauheim*. In summer the greatest monthly average amount in *Davos* was slightly higher than that at *Johannesburg*.

Nairobi experienced during practically every month in the period under investigation a greater amount of radiation than the other places. This is mainly due to the greater altitudes of the sun as well as to the fact that very frequently, white cumuli clouds were scattered over the sky, causing a further increase in radiation by reflection.

Bad Nauheim received a very much smaller amount of radiation than *Davos* and the other places all the year round.

The ratio between the month with the largest and the month with the smallest amount of radiation was $2.0 : 1$ at *Johannesburg*. In *Davos* it was $4.5 : 1$ and in *Bad Nauheim* $10.4 : 1$, which shows distinctly that the difference between summer and winter is very much more pronounced in these two latter places than nearer the equator.

Referring to the *yearly* total amount of sun and sky radiation the figures show that the slightly greater amount at *Davos* during the two midsummer months compared with *Johannesburg* does not compensate for the smaller amount during the other months. Taking the yearly total amount at *Davos* as 100 per cent., *Johannesburg* received 122 per cent., whilst *Bad Nauheim* obtained only 69 per cent. It has to be emphasized, however, that *Davos* does not represent general European conditions. On account of its situation in a high altitude and the clear and frequently cloudless atmosphere over the Alps the radiation in particular is different from that in the lowlands. *Bad Nauheim* is more likely to represent the general conditions in Europe.

A further interesting item may be stressed, i.e. the yearly average number of hours with sunshine (Table 4). They show very clearly the excessive amount of sunshine in *Johannesburg*, and the superiority of *Davos* over *Bad Nauheim*. The yearly average for London is 3.8 hours of sunshine per day.

These comparisons may briefly be summarised as follows:—

In winter the amount of sun and sky radiation at Johannesburg was distinctly larger than in Davos (Switzerland) at similar altitude above sea-level. It was 5 to 10 times larger than in Bad Nauheim (Germany) at a low altitude above sea-level.

During two months in midsummer the amount at Davos was slightly larger than that during the respective months in Johannesburg.

Nairobi (Kenya) experienced during the six months under investigation a greater amount of radiation than any of the other places mentioned in this comparison.

The ratio between highest summer and lowest winter readings per month was $2.0 : 1$ at Johannesburg, $4.5 : 1$ at Davos, and $10.4 : 1$ at Bad Nauheim.

The yearly total amount at Johannesburg was 122 per cent. of what was received in Davos; Bad Nauheim obtained only 69 per cent. of that amount.

F. THE RESULTS OF THE COOLING TEMPERATURE MEASUREMENTS.

The following chapter deals with the results of the cooling temperature measurements.

It has been mentioned before (see page 351) that the cooling temperature is a well-defined physical unit which is approximately equal to the mean skin temperature of a resting, naked human body exposed in the open and that it indicates the variations of the combined bioclimatic factors of radiation, wind and air temperature.

When studying the bioclimatic conditions of an area it is preferable to examine the detailed figures of the cooling temperature rather than any mean values. On the other hand, the original data collected during the Survey 1937/38 amounted to more than 24,000 hourly readings, an amount of figures which is too unwieldy to be dealt with in this paper. The number of figures was, therefore, reduced in such a way that the characteristic features of the conditions which are of general biologic interest were made apparent by comparatively few figures. The four outstanding items of general biological interest chosen for this are discussed below.

Firstly, there is the average change of the cooling temperature during the days of each month and the change of conditions during the course of the year. These results can be studied by means of the graphs which are given separately for each of the six Solar Radiation Stations. [They are also given in the form of a table (Tables 13 and 13A) (page 419) to make a comparison of the results obtained at the various stations easier.] These graphs were obtained from the original hourly readings by calculating the average values per month for each hour of the day.

The *second* item is the difference between the highest and the lowest average cooling temperature readings. These are of biological interest because they represent the extremes to which the human body may be exposed. These daily ranges are given in Part A of the tables which contain the detailed results of the cooling temperature measurements for each station. Another significant range is that between 6 p.m. and 6 a.m., as this drop represents the conditions during the nights. These data are given together with the *daily* range in Part A of the above-mentioned tables.

The *third* extract of the cooling temperature readings is based on the consideration that biologists are particularly interested in sudden changes of the conditions to which organic life is exposed. The figures which can give information on this point are those which represent the frequency of large and rapid variations of the cooling temperature. A change of 10° or more during a time interval of one hour was considered to be large, that is to say, if the cooling temperature changed by more than 10° during one hour, this hour was counted as being one with a large variation. The total number of hours with such large variations were counted for each month and are given in Part B of the tables, together with the number of days on which these large variations occurred.

The *fourth* detail of cooling temperature measurements which concerns the biologist is the occurrence of periods of hours with very high or very low cooling temperatures. During these hours a great strain would be experienced by a human body if exposed in the open. Careful investigations in Europe have proved that for a cooling temperature above 40° or below 20° the physiological strain to a naked exposed human body would be so great that the danger of overheating or overcooling was imminent. Periods of more than 5 hours with cooling temperatures higher than 40° or lower than 20° were, therefore, counted for each station and the number and average duration of such periods are given in Part C of each table.

In addition to the detailed results given separately for each station, a comparison of the cooling temperature conditions at the six stations in the Union is presented.

THE RESULTS OF THE COOLING TEMPERATURE MEASUREMENTS AT EACH OF THE SIX STATIONS.

1. *The Cooling Temperature at Johannesburg.*

The mean monthly cooling temperature for each hour per day is given in Graph IX (see also Table 13 and 13A, page 419) where the horizontal divisions represent degrees centigrade and the vertical divisions the 24 hours of the day.

During the course of the year a steady increase of the cooling temperature took place from July until November inclusive. December readings, on the other hand, showed a distinct decrease compared with those in November. During both months the night cooling temperatures were nearly the same, but the day readings in December were 7° lower. In January and February the cooling effect of the rains were still noticeable, whilst in March rather high readings were recorded. The approach of winter, coincident with another outbreak of rains, resulted in very low readings during April. During May the night readings were 5° lower than during April.

A. Ranges.—The difference of the daily average curves in winter and summer is at once evident when looking at the graph, the daily range being much greater in winter than in summer. The exact figures are given in Part A of Table 6. It shows that the difference between the highest day- and the lowest night readings was very large all the year round, but particularly so during the winter months, when a clear sky permitted a strong irradiation from the earth at night. During the rainy season clouds frequently prevented this intensive loss of heat from the earth and the average range of the cooling temperature between day and night became smaller. Nevertheless the yearly average range was 18° .

The average drop of the cooling temperature during the nights (given in the second line of Part A of Table 6), was also great except during the rainy season.

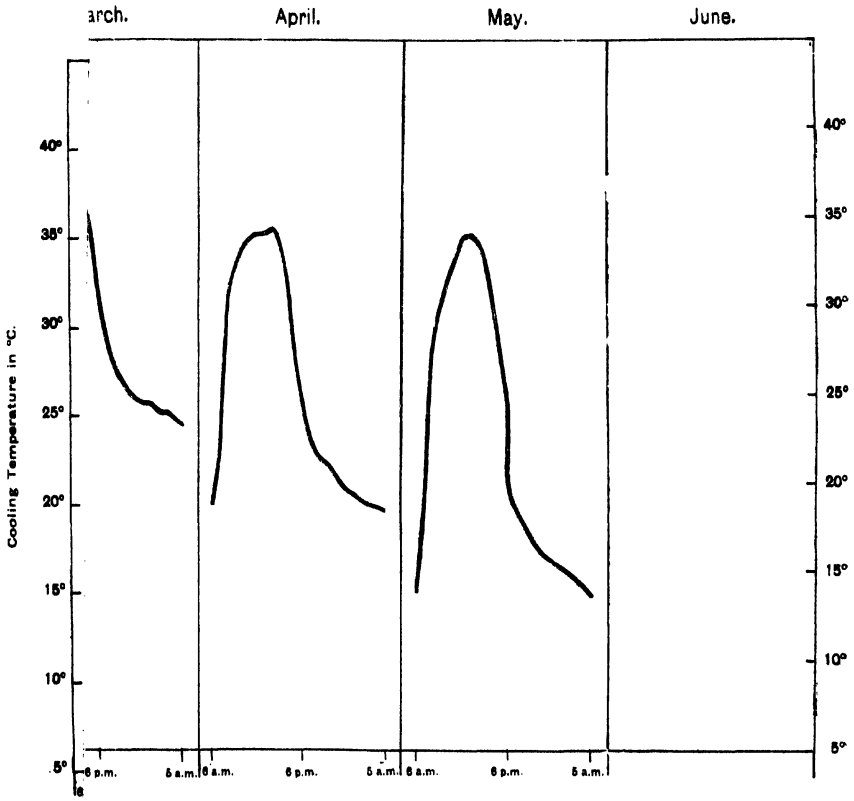
TABLE 6.

Johannesburg, Cooling Temperature: (A) Ranges, (B) Frequency of large Variations and (C) Periods with High and Low Values.

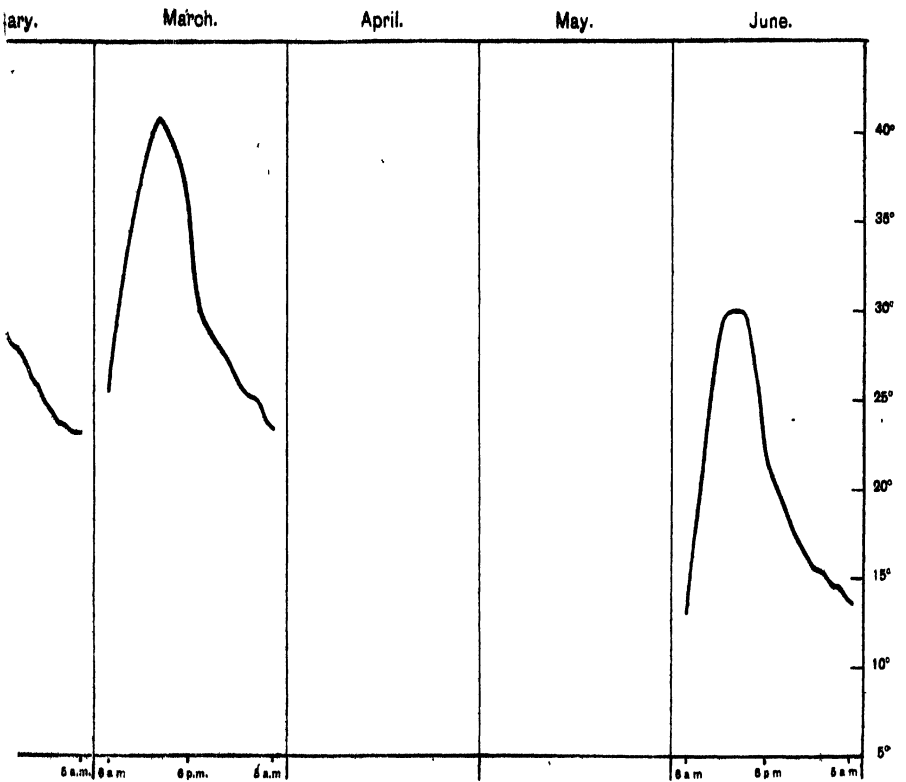
Month.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
A. { Range highest—lowest hourly mean value.... Range 6 p.m.—6 a.m.)...	21° 7°	24° 10°	21° 9°	18° 8°	18° 7°	13° 3°	14° 4°	16° 6°	18° 7°	16° 6°	20° 7°	— —
B. { Total number of hours with variations greater than 10°..... Number of days on which these variations oc- curred.....	18 19	22 21	23 19	21 12	37 25	43 20	38 17	33 15	55 27	31 22	31 25	— —
C. { Average number of hours per day with more than 40° cool. temp..... Number of days on which these high cool. temp. were recorded.....	0 0	0 0	6 5	6 7	7 16	6 3	6.5 6	5 1	6.5 15	6 2	0 0	— —
{ Average number of hours per day with less than 20° cool. temp..... Number of days on which these low cool. temp. were recorded.....	15 24	13 31	12 26	10 7	6 1	16 3	14 1	9 3	0 0	9.5 13	12 30	— —

B. Variations.—Part B of Table 6 gives for each month the total number of hours during which a variation of cooling temperature of more than 10° was recorded. The fourth line in the table contains the number of days on which these large variations occurred. For instance, in March there were 27 days with 55 jumps. This indicates that on 27 out of the 31 days of this month considerable and rapid variations of the cooling temperature took place, and that quite frequently they occurred more than once during a day. In Johannesburg the number of hours and days with large and rapid variations of the cooling temperature was great during the whole year under investigation with no distinct maximum of occurrence in any season. Another fact, which can not be seen from the figures, is worth while mentioning, namely that during March, 1938, abnormal drops of more than 20° occurred on 4 separate occasions.

C. High and Low Values.—The average number of hours per month with readings above 40° and those below 20° are given in Part C of Table 6. In addition, the number of days on which these outstanding readings were recorded, are indicated. For instance: In September there were 5 days with readings above 40°. During each of these days the high readings occurred on an average for 6 hours. During the same month cooling temperature readings below 20° were registered over average periods of 12 hours on each of 26 days. Outstanding amongst the figures in Part C of Table 6 are those for November and March. We see here that the cooling



ire



temperature was continuously above 40° for about 7 hours on half the number of days in each of these months. During August, September and May readings below 20° were obtained on an average of 12 successive hours practically every day.

A detailed study of the table will illustrate more clearly the characteristic features of the cooling temperature conditions at Johannesburg. The same refers to the results obtained at the other stations.

2. The Cooling Temperature at **Bloemfontein.**

Graph X shows the mean hourly values of the cooling temperature at Bloemfontein. They increased very steadily from July until November. Then followed five months with very similar average values. In June, 1938, when the instruments were erected at the Boyden Station Observatory, the cooling temperature readings were very low.

TABLE 7.

Bloemfontein, Cooling Temperature: (A) Ranges, (B) Frequency of large Variations and (C) Periods with High and Low Values.

Month.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
A. { Range highest—lowest hourly mean value.... Range 6p.m.—6 a.m.....	16° 5°	19° 8°	20° 9°	19° 9°	17° 9°	16° 8°	17° 8°	15° 7°	17° 8°	— —	— —	17° 7°
B. { Total number of hours with variations greater than 10° Number of days on which these variations occurred.....	6 6	7 6	17 11	9 8	8 5	11 8	34 17	16 9	11 5	— —	— —	10 5
C. { Average number of hours per day with more than 40° cool. temp..... Number of days on which these high cool. temp. were recorded.....	0 0	5 1	5 8	6 12	7 18	7 15	7 15	7 6	6 16	— —	— —	0 0
{ Average number of hours per day with less than 20° cool. temp..... Number of days on which these low cool. temp. were recorded.....	15 29	10 30	11 14	8 8	10 1	5 1	5 1	5 1	0 0	— —	— —	13 26

A. *Ranges.* The effect of the rainy season on diminishing the daily range of cooling temperature was less pronounced in Bloemfontein than in Johannesburg, the difference between day and night readings being large the whole year round. The average daily range, namely 17° , was 1° lower than at Johannesburg.

SOUTH AFRICAN SOLAR RADIATION SURVEY.

The average drop during the nights was also great, being approximately 8° .

B. Variations: The frequency of large and rapid changes of the cooling temperature was distinctly smaller than in Johannesburg. Only January showed a relatively great number of jumps of more than 10° during one hour, namely 34 times on 14 days.

C. High and Low Values: During the months October, November, December, January and March periods of 6 to 7 hours with cooling temperatures above 40° were recorded quite frequently. The winter months, July and August, 1937, and June, 1938, showed altogether only one day with such high readings. These winter months, however, showed numerous periods with very low readings. Cooling temperatures below 20° for 10-13 hours per day occurred practically every day.

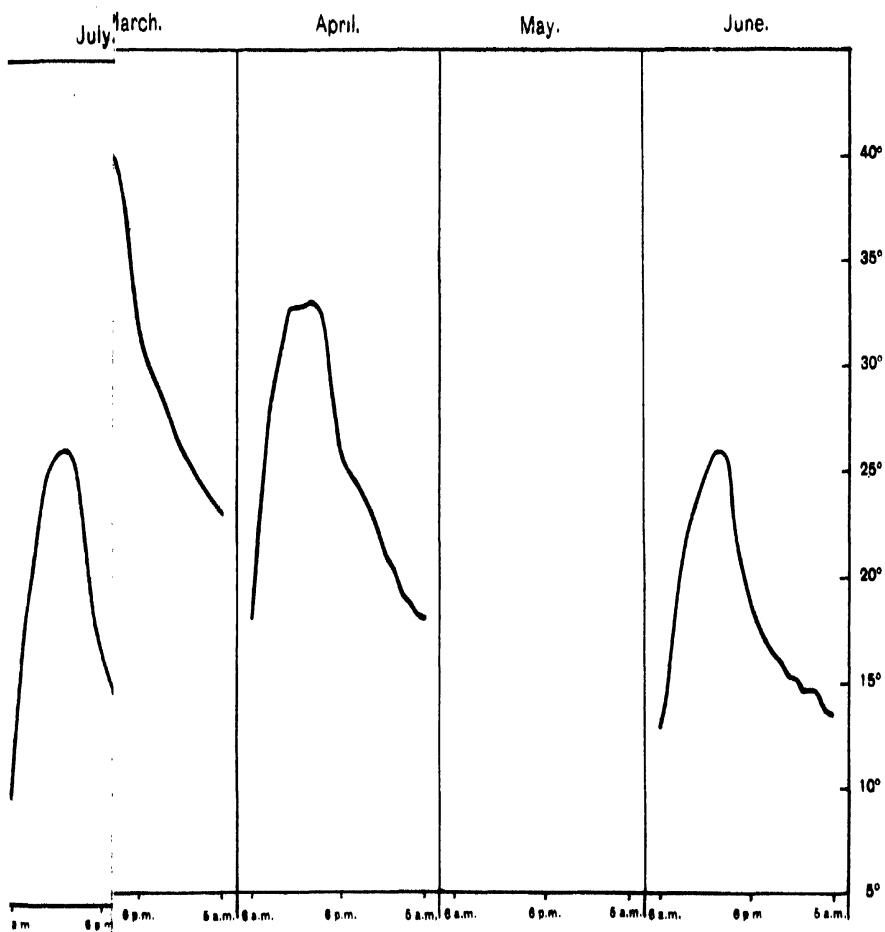
3. The Cooling Temperature at Nelspoort Sanatorium.

Measurements of the cooling temperature at Nelspoort were unfortunately not taken from the middle of December, 1937, until the beginning of March, 1938, and again from the beginning of May until the middle of June, 1938.

TABLE 8.

Nelspoort Sanatorium, Cooling Temperature: (A) Ranges, (B) Frequency of Large Variations and (C) Periods with High and Low Values.

Month.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
A. { Range highest—lowest												
hourly mean value.....	17°	18°	18°	18°	20°	16°	—	—	18°	15°	—	—
Range 6 p.m.—6 a.m.....	7°	9°	9°	10°	9°	8°	—	—	9°	8°	—	—
B. { Total number of hours												
with variations greater												
than 10°	16	12	20	9	31	22	—	—	15	21	—	—
Number of days on which												
these variations oc-												
curred.....	14	11	17	8	19	12	—	—	13	13	—	—
C. { Average number of hours												
per day with more than												
40° cool. temp.....	0	0	6	6	7	0	—	—	6.5	5	—	—
Number of days on which												
these high cool. temp.												
were recorded.....	0	0	3	4	10	0	—	—	17	1	—	—
Average number of hours												
per day with less than												
20° cool. temp.....	16	13	13	10	7	9	—	—	0	9	—	16
Number of days on which												
these low cool. temp.												
were recorded.....	28	22	24	16	10	8	—	—	0	16	—	14



Temperature

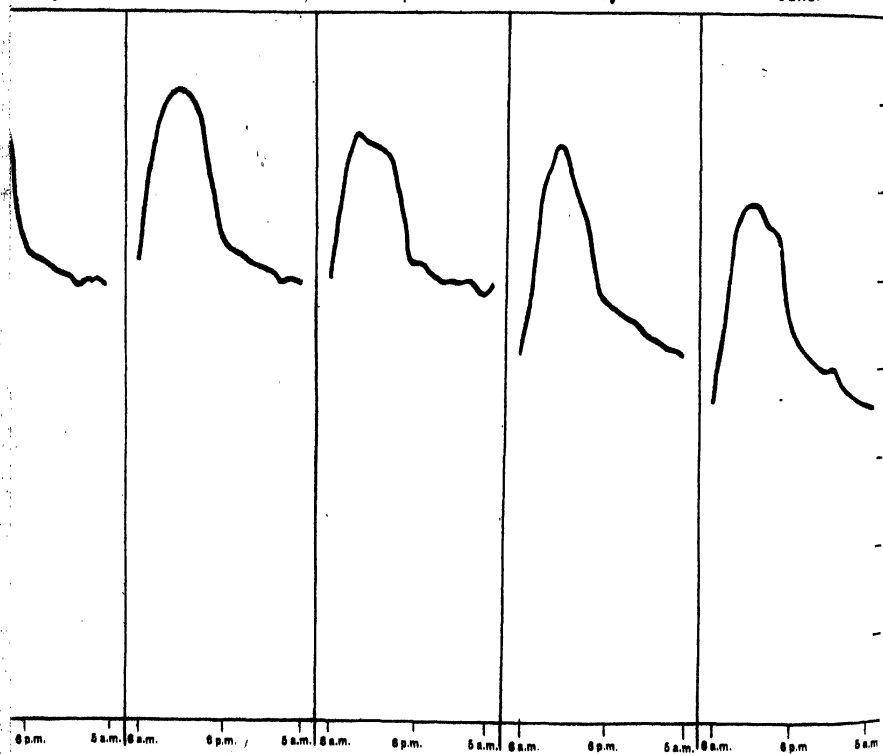
February.

March.

April.

May.

June.



The hourly mean cooling temperature for Nelspoort is given in Graph XI. As at the two other inland stations, Johannesburg and Bloemfontein, the hourly mean cooling temperature increased during the course of the year until December, when the readings showed a distinct drop. The difference between March and April was very marked; the mean highest readings were 8° lower in the latter month. During the second half of June, 1938, very low cooling temperatures were recorded.

A. Ranges.—The differences between the highest and the lowest hourly readings were great all the year round, the average being also 17° , as in Bloemfontein.

The average nightly range was also the same as in Bloemfontein, namely 8° .

B. Variations.—Large and rapid changes of the cooling temperature were more frequent in Nelspoort than in Bloemfontein, but they were less numerous than in Johannesburg.

C. High and Low Values.—The occurrence of very high and very low cooling temperatures during the course of the year cannot be given as the readings are incomplete. It can only be said that during the winter months July and August, 1937, and June, 1938, readings above 40° were never recorded. In that respect the conditions were similar to those at the other inland stations. As far as readings are available they seem to indicate that during the remaining months the frequency of periods with more than 40° cooling temperature is smaller in Nelspoort than in Johannesburg and Bloemfontein. Periods of 13-16 hours per day with cooling temperatures below 20° occurred during most days in July, August and September, 1937. The remaining months also showed a comparatively large number of long periods with very low cooling temperatures.

4. *The Cooling Temperatures at Durban.*

When considering the cooling temperature at Durban (given in Graph XII) there are two facts which are most striking; firstly the mean cooling temperature was rather high all the year round, and secondly it varied comparatively little during the course of the year. This is due to the influence of that great store of warmth, the ocean, which tends to lessen the variation of temperature from day to night and from summer to winter. During summer the sea is heated up by the sun and much heat is stored. A great deal of the heat is given off in winter and consequently there is less fluctuation of temperature at the coast than inland.

A third outstanding feature of the cooling temperature at Durban is that the daily ranges, given in Part A of the following table, were small during summer as well as during winter.

A. Ranges.—The yearly average drop from the highest to the lowest readings of the cooling temperature was only 11° ; it varied very little during the course of the year. The range during the nights was particularly small, it averaged only 2.5° . This illustrates very significantly the small refreshing qualities of the nights of the coastal climate at Durban.

TABLE 9.

Durban, Cooling Temperature: (A) Ranges, (B) Frequency of large Variations and (C) Periods with High and Low Values.

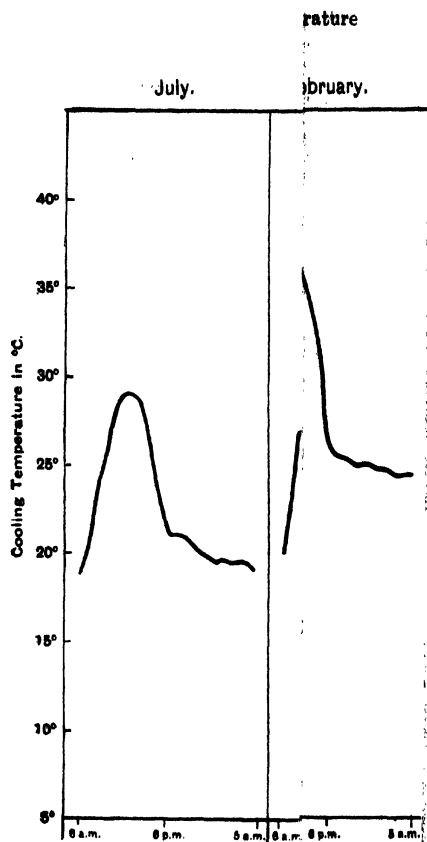
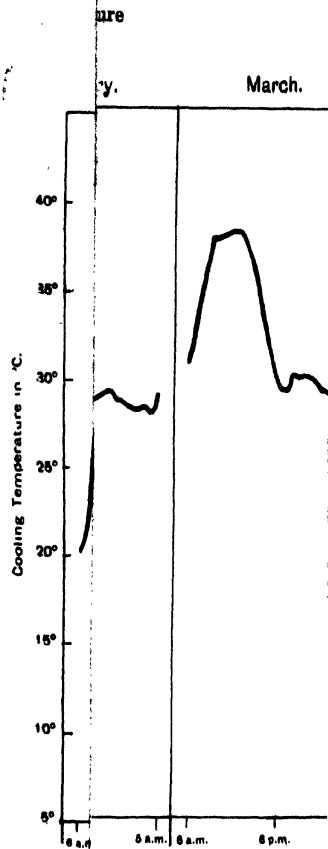
Month.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
A. { Range highest—lowest hourly mean value	12°	11°	12°	10°	10°	10°	9°	11°	11°	9°	11°	11°
Range 6 p.m.—6 a.m.	4°	4°	4°	2°	2°	1°	2°	2°	2°	1°	3°	4°
B. { Total number of hours with variations greater than 10°	13	6	11	11	7	6	8	12	2	6	6	6
Number of days on which these variations oc- curred	10	6	10	4	3	5	6	5	2	4	6	6
C. { Average number of hours per day with more than 40° cool. temp.	0	0	0	6	9	7	8	6	6.5	6	0	0
Number of days on which these high cool. temp. were recorded	0	0	0	3	4	6	9	11	14	7	0	0
Average number of hours per day with less than 20° cool. temp.	6	5	0	0	0	0	0	0	0	0	0	5
Number of days on which these low cool. temp. were recorded	5	1	0	0	0	0	0	0	0	0	0	3

B. Variations.—There were comparatively few days with large and rapid variations, nevertheless they occurred, most frequently during the months of July and September, 1937.

C. High and Low Values.—During the five months (July, August and September, 1937, and May and June, 1938) not a single period of 5 or more hours occurred with a cooling temperature of over 40°. Of the remaining months only February and March showed more than 10 days each with such high readings. In November and January a period of 9 and 8 hours were experienced on 4 and 9 days respectively. On the whole it can be said that the amount of periods with very high cooling temperatures was remarkably small, smaller than at any of the other stations. Cooling temperature values of less than 20° occurred only on very few days in July and August, 1937, and in June, 1938. The remaining 9 months had no periods of 5 hours or more with such low readings.

5. The Cooling Temperature at Port Elizabeth.

The graph of the mean hourly cooling temperature for Port Elizabeth (Graph XIII) also shows the influence of the sea. The mean cooling temperature was fairly constant the whole year round. There was a steady but not very pronounced increase from winter to summer.



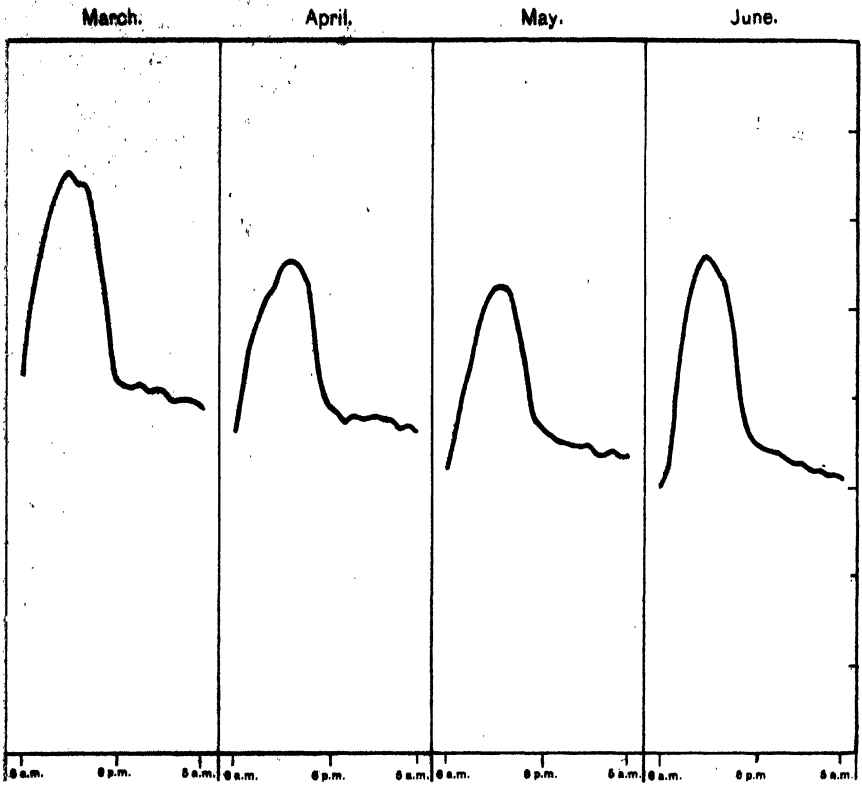


TABLE 10.

Port Elizabeth, Cooling Temperature: (A) Ranges, (B) Frequency of large Variations and (C) Periods with High and Low Values.

Month.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
A. { Range highest—lowest hourly mean value.... Range 6 p.m.—6 a.m.....	12° 2°	13° 3°	11° 1°	11° 2°	11° 1°	10° 1°	10° 0.4°	10° 2°	9° 1°	9° 1°	10° 1°	12° 2°
B. { Total number of hours with variations greater than 10°..... Number of days on which these variations occurred.....	14 11	17 12	14 9	11 10	14 12	14 10	17 12	7 7	4 4	8 4	8 6	14 12
C. { Average number of hours per day with more than 40° cool. temp..... Number of days on which these high cool. temp. were recorded.....	0 0	8 5	0 0	7 1	5 2	7.5 2	8 7	8 7	5.5 5	7 1	0 0	0 0
{ Average number of hours per day with less than 20° cool. temp..... Number of days on which these low cool. temp. were recorded.....	10 15	8 7	13 6	8 6	0 0	0 0	0 0	0 0	0 0	6 2	10 6	10 15

A. Ranges.—The range between highest and lowest mean cooling temperature was on an average the same as in Durban, i.e., 11°; the variation of the range during the course of the year was also small. The average decrease during the nights was only 1.5°.

B. Variations.—Rapid variations of more than 10° during one hour occurred quite frequently and were more or less evenly distributed throughout the year.

C. High and Low Values.—Periods of 5 hours or more with a cooling temperature above 40° were not very often experienced. August, January and February had 5, 7 and 7 days respectively during which high readings for a period of 8 hours were recorded. It is remarkable that the winter month of August showed such long periods of high cooling temperatures on 5 days.

During the 5 summer months (November–March) periods with values below 20° were not recorded. Five other months experienced a few days each with low reading periods, but the two winter months July, 1937, and June, 1938, recorded 15 days each with low cooling temperatures over average periods of 10 hours.

6. *The Cooling Temperature at Capetown.*

The variations of the cooling temperature during the course of the year, as given in Graph XIV, were not very great; a slight and rather steady increase from winter to summer took place.

TABLE 11.

Cape Town, Cooling Temperature: (A) Ranges, (B) Frequency of large Variations and (C) Periods with High and Low Values.

Month.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
A. { Range highest—lowest hourly mean value.... Range 6 p.m.—6 a.m.....	10° 2°	13° 3°	12° 1°	15° 3°	14° 2°	14° 2°	13° 2°	13° 2°	13° 2°	9° 1°	10° 2°	13° 2°
B. { Total number of hours with variations greater than 10°..... Number of days on which these variations occurred.....	11 6	13 8	24 13	28 18	16 10	6 5	13 5	1 1	5 3	11 9	9 6	17 7
C. { Average number of hours per day with more than 40° cool. temp..... Number of days on which these high cool. temp. were recorded.....	0 0	6 2	6 1	7 3	5 5	7 4	7 8	6 3	5 3	5 1	0 0	5 4
C. { Average number of hours per day with less than 20° cool. temp..... Number of days on which these low cool. temp. were recorded.....	11 23	10 20	12 12	12 3	10 1	0 0	0 0	0 0	0 0	0 0	9 6	8 12

A. Ranges.—The average range between highest and lowest readings was 13°, a little greater than at the other coastal stations. The variation of this range during the course of the year was irregular.

B. Variations.—Rapid variations of more than 10° during one hour occurred in every month, but more frequently during the winter.

C. High and Low Values.—Periods with cooling temperatures of 40° and more occurred on a few days in every month except July, 1937, and March, 1938. The number of days with such high readings was, however, small all the year round.

Periods with readings below 20° were quite frequently recorded during September, 1937, and June, 1938.

Table 12 gives in the form of yearly averages for all stations a summary of the data already given. This table serves to emphasize the results already discussed and it enables one to compare the results of the different stations.

TABLE 12.

Cooling Temperature.—(A) Yearly Average Ranges, (B) Yearly Frequency of large Variations and (C) Yearly Frequency of Periods with High and Low Values at the Six Stations in the Union.

	Stations.	Johan- nes- burg.	Bloem- fontein.	Nels- poort.	Durban.	Port Eliza- beth.	Cape Town.
A.	Yearly average range highest- lowest hourly mean values Yearly average range between 6 p.m. and 6 a.m.	18°	17°	17°	11°	11°	13°
		7°	8°	8°	2.5°	1.5°	2°
B.	Total number of hours with variations greater than 10° Total number of days on which these variations occurred.....	334	129	146	94	142	154
		203	80	107	67	109	91
C.	Yearly average number of hours per day with more than 40° cooling tempera- ture..... Total number of days on which these high cool. tem- peratures were recorded..	6	6	6	7	7	6
		55	91	35	54	30	34
	Yearly average number of hours per day with less than 20° cooling tempera- ture..... Total number of days on which these low cool. tem- peratures were recorded..	12	9	12	5	9	10
		139	111	138	9	57	77

COMPARISON OF THE COOLING TEMPERATURE READINGS AT SIX STATIONS IN THE UNION.

The following points were chosen for a comparison of the results obtained at the six stations in the Union :

1. The mean value *for each hour* for the various seasons, i.e. the daily readings for the hours 1-2 a.m., 2-3 a.m. etc., were averaged over periods of three months. By means of these figures the seasonal average conditions *during the course of the day* can be compared with each other.

2. All the cooling temperature readings in each month were averaged. These values present the average change of conditions *during the course of the year*.

3. The mean monthly values of the daily maximum and minimum were calculated and are given together with the absolute highest and lowest readings for each month.

The following text deals with these three items separately.

1. *The Mean Seasonal Cooling Temperatures for each Hour of the Day.*

The mean seasonal cooling temperatures for each hour of the day are given in Table 14 and 14A, pages 423-426. The average is taken over periods of three months except during winter, which only includes the readings of two months, namely July and August, 1937. The following groups of months were taken to represent the different seasons:—Spring: September, October and November; summer: December, January and February; autumn: March, April and May, and winter: July and August, 1937. The summer and the winter average values are given in the form of a graph (Graph XV).

Graph XV discloses the following:—

(a) *Inland Stations: Winter.*—The cooling temperature at Johannesburg showed the greatest extreme values, the days having higher readings and the nights lower readings there than at any of the other inland stations. Bloemfontein registered distinctly higher values at night but in daytime the cooling temperature was lower than at Johannesburg. In Nelspoort the values were only a little higher at night, but distinctly lower during the days than at Johannesburg.

The average conditions in autumn and spring in Johannesburg approached nearer to the summer than to the winter conditions.

Another significant feature at the inland stations was that the rapid decrease of the cooling temperature in the afternoon continued even after sunset. Particularly was this the case at Johannesburg.

Summer.—Seasonal mean values cannot be compared as the readings were not registered continuously at Nelspoort Sanatorium.

(b) *Coastal Stations.*—The highest seasonal mean values of the cooling temperature during day and night and also in winter and summer were obtained at Durban; the average readings were only a little lower at Port Elizabeth and another 2° to 3° lower at Cape Town. In general, the average conditions at the three coastal stations showed no very distinct differences, although the individual daily readings sometimes varied considerably.

In contrast to the inland stations the average drop of the cooling temperature during the nights at the coastal stations was small for both winter and summer. The rapid decrease in the afternoon only lasted until sunset, immediately after which only a gradual drop was recorded.

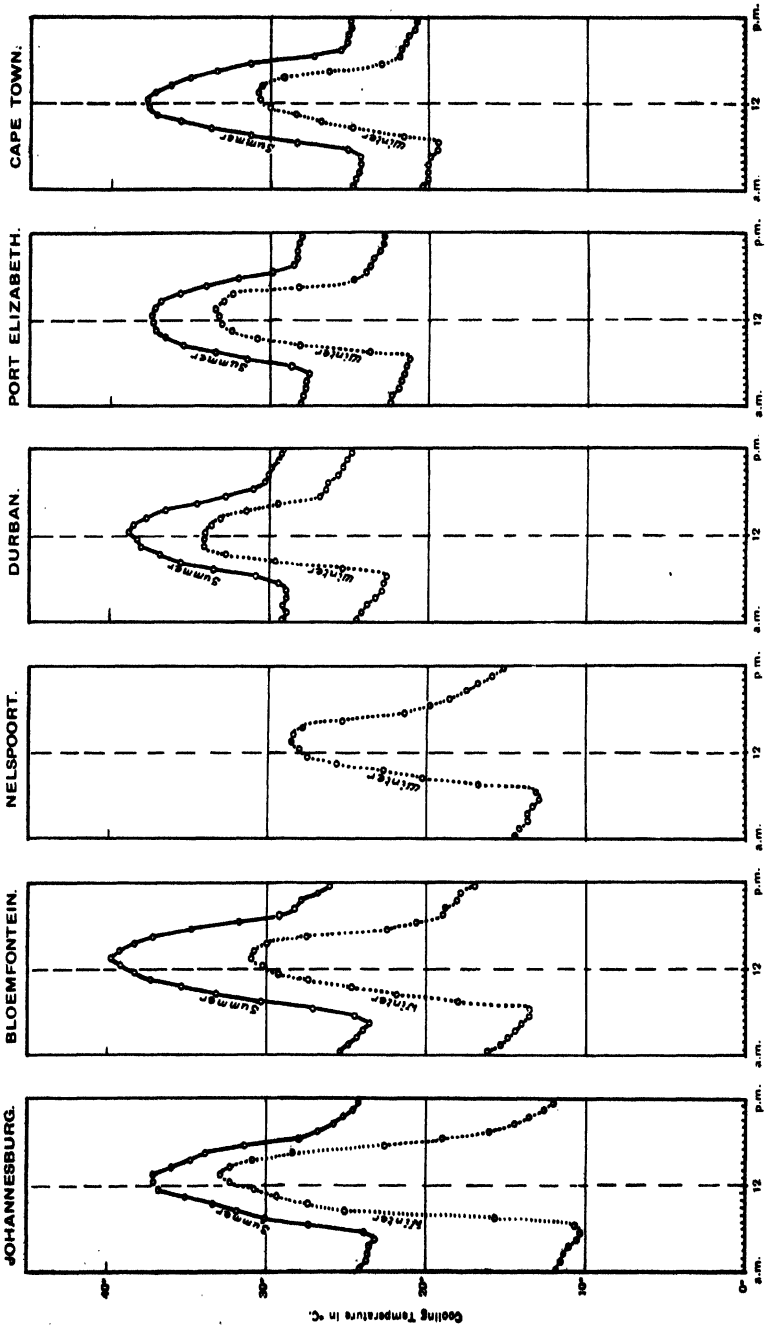
2. *The Mean Cooling Temperature for all Hours of Each Month.*

The mean values of all hourly readings in each month are given in Graph XVI. This graph represents the average conditions of the cooling temperature at the various stations during the course of the year.

The most significant feature of this graph is the great increase of the mean cooling temperature from winter to summer at the inland stations. This average increase from July until November inclusive

GRAPH XV.

Mean Cooling Temperature of *Each* Hour of the Day for the Winter and
and Summer Season at Six Stations in the Union.



amounted in Johannesburg to 14.3° , Bloemfontein 13.8° and Nelspoort Sanatorium 12.8° . The increase over the same period for the coastal stations was: 4.3° in Durban, 5.1° in Port Elizabeth and 5.9° in Capetown.

Graph XVI shows further, that the monthly average cooling temperature in winter was distinctly lower at the inland stations than at the coastal stations. In summer, however, this difference was not very pronounced. On the contrary, the mean cooling temperature at the coast and in the interior was fairly similar. This may be emphasized by the following figures which give the mean cooling temperature for the summer and the winter seasons. Johannesburg 29.2° , Bloemfontein 31.0° , Nelspoort, Durban 32.7° , Port Elizabeth 31.8° and Capetown 29.7° . The respective figures for the two winter months July and August, 1937, were 19.7° , 21.0° and 19.3° at the inland stations and 27.9° , 26.1° and 25.7° at the coastal stations.

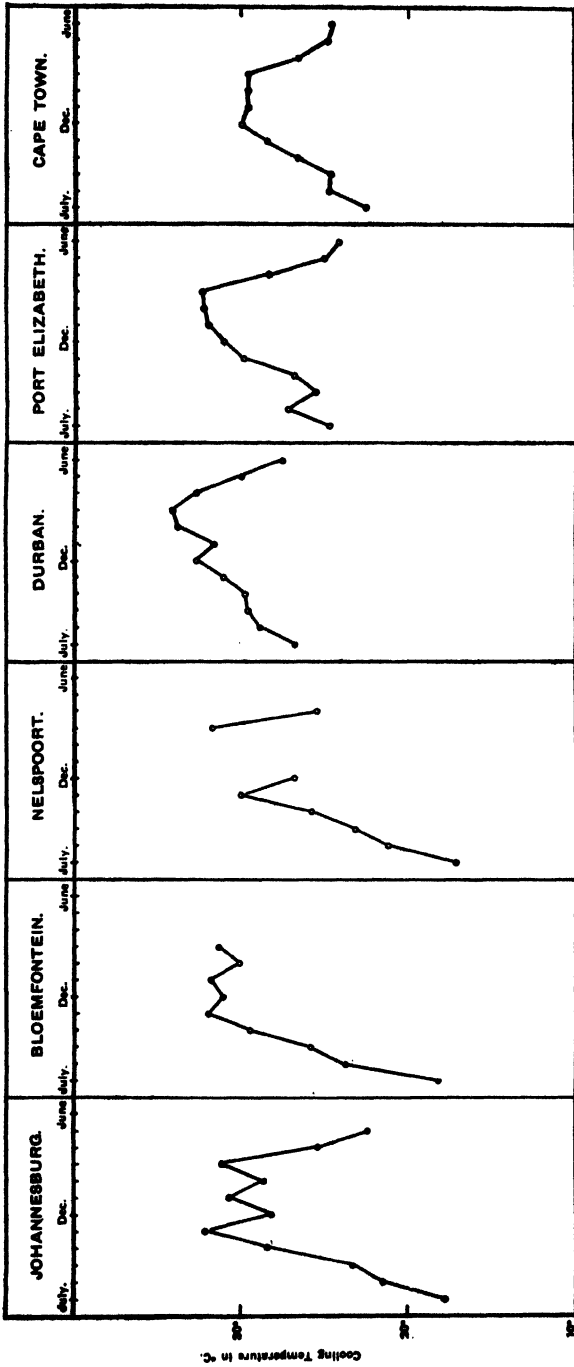
3. *The Mean, and the Absolute Highest and Absolute Lowest Readings of the Cooling Temperature per Month at the Six Stations in the Union.*

As already mentioned, extreme values are of special biological interest. They are not only represented by the number of periods with very high and very low cooling temperatures already discussed, but also by the actual maximal and minimal values of the cooling temperature. These are given in Tables 15 and 15A (pages 427 to 430). The former contains the average values for each month and the latter the absolute highest and absolute lowest readings. These tables enable one to make a twofold comparison. Firstly the maxima and minima at each station can be compared month by month and secondly the values for the same month at each station can be compared.

The figures in both tables are recommended for careful study as they contain some interesting information, which is too detailed and rather confusing to give in this text. Nevertheless a few outstanding features may be mentioned.

Mean Maxima.—The mean maximum of the cooling temperature at the inland stations was never for a long period distinctly higher or lower than at the coastal stations. There were however, a few months where such a distinct difference did exist. During November, January and March the cooling temperature maxima at the inland stations were higher than at the coastal stations. An exception to this occurred at Durban in March, when the readings were just as high as at the inland stations. It is also not definite that this applies to Nelspoort in January, as these readings are not available. The highest mean maxima were registered in Durban during 7 out of the 12 months under investigation. During two other months Durban recorded the second highest maxima, Cape Town registered during 5 months the lowest maxima.

GRAPH XVI.
Mean Cooling Temperature of All Hours of Each Month at Six Stations in the Union.



Mean Minima.—A very pronounced difference is shown between the minima at the inland stations and at the coastal stations. The minima were always distinctly lower at the inland stations, the only exception being Cape Town which in November recorded a lower average minimum. In March the Cape Town readings were the same as at Johannesburg and Bloemfontein. Of the three coastal stations, Cape Town recorded the lowest mean minima during every month of the year except June, 1938.

Ranges.—The differences between mean maxima and mean minima varied little at the coastal stations during the course of the year. The ranges were always greater inland than at the coast.

The *absolute highest* cooling temperatures (Table 15A, page 429) show three maxima above 50° , namely in August and January at Port Elizabeth and in November at Johannesburg. During four months (September, November, March and April) the highest values were recorded at Johannesburg and Bloemfontein, during the remaining months they occurred at one of the coastal stations.

The *absolute minima* are much lower at the inland than at the coastal stations. The lowest cooling temperature registered during the year under investigation was 4° at Johannesburg in September, 1937.

Summarizing, the main facts emerging from the comparison of the cooling temperature measurements at the various stations, are:—

(a) *Inland Stations.*

1. *During winter the mean values show the greatest extremes during day and night at Johannesburg. Bloemfontein recorded higher readings at night, and Nelspoort distinctly lower readings during daytime, than Johannesburg.*

2. *The rapid decrease of the cooling temperature in the afternoon continued after sunset.*

3. *The average increase of the mean cooling temperature from winter to summer was great at all three inland stations.*

4. *The mean maxima were in general not higher than at the coastal stations except during November, January and March.*

5. *The mean minima, however, were always distinctly lower than at the coastal stations.*

6. *The ranges between the mean maxima and mean minima were always greater than at the coastal stations.*

7. *The absolute highest cooling temperature was measured at Johannesburg in November, 1937; the absolute lowest was also recorded in Johannesburg, in September, 1937.*

(b) Coastal Stations.

1. *The average conditions at the three coastal stations showed no very distinct differences. Throughout the year Durban's mean cooling temperature values were the highest. Next in order was Port Elizabeth, followed by Cape Town.*

2. *The rapid decrease of the cooling temperature in the afternoon only lasted until sunset, immediately after which the drop became much more gradual.*

3. *The average increase of the mean cooling temperature from winter to summer was small at all three coastal stations.*

4. *During 5 months the highest and during 2 months the second highest mean maxima were measured at Durban. Cape Town had during 5 months the lowest mean maxima.*

5. *The lowest mean minima were recorded in Cape Town during each of the 12 months except June, 1933.*

6. *The ranges between mean maxima and mean minima differed little during the course of the year.*

7. *Cooling temperatures above 50° were recorded in Port Elizabeth during August, 1937, and January, 1938.*

(c) The monthly average cooling temperature in winter was distinctly lower at the inland than at the coastal stations. In summer this difference was not pronounced.

In addition to the results presented in this paper data on the intensity of the direct solar radiation and various regions of the spectrum were taken periodically at Johannesburg, Onderstepoort, Bloemfontein, Stellenbosch and Durban. The results of the observations at Johannesburg and Stellenbosch have been published by the respective authors. [Matheson (1939), Richards (1939), De Villiers (1939)]. It is hoped to publish the data from the other stations in the future as also readings of the total amount of sun and sky radiation and of the cooling temperature taken at the Natal National Park.

SUMMARY.

The results of the physical measurements of the total amount of sun and sky radiation and the cooling temperature at 6 stations in the Union may be summarized as follows:—

A. RADIATION.

1. *How does the amount of radiation at the inland stations compare with that at the coastal stations?*

The amount of radiation obtained at the inland stations exceeded the amount at the coastal stations all the year round.

2. *Which station received the greatest, and which the smallest amount of radiation during the course of the year?*

During nine out of twelve months the greatest amount of radiation was obtained in the climatic zone of the highveld. During the remaining three months (December, January and February) the greatest amount was received at Cape Town.

The smallest amount of radiation was obtained during all twelve months at the coastal stations. In five of the twelve months Cape Town recorded the least, during five other months Durban received the smallest amount.

3. *During which month was the greatest and during which the smallest amount of radiation obtained at each station?*

At each station the greatest amount of radiation occurred during the months November or December, 1937. The smallest amounts were recorded during the winter months of July, 1937, and June, 1938.

4. *What was the ratio between the greatest and the smallest amount of radiation at each station?*

Johannesburg registered during the month of maximum radiation twice as much solar energy as it did during the month of minimum radiation. Comparable ratios were: 3·4 : 1 for Cape Town; nearly 3 : 1 for Port Elizabeth and 2 : 1 for Durban.

5. *How did the amount of radiation at each station vary during the course of the year?*

The amount of radiation at Johannesburg during the course of the year was rather irregular. At Bloemfontein and Nelspoort the increase of the monthly amount with the increase of the altitude of the sun was progressive. At Durban great variations in the amount of radiation was registered from month to month. Port Elizabeth showed a fairly regular distribution over the year. In Cape Town the amount also increased and decreased steadily in accordance with the sun's altitude and showed particularly high readings in December and January.

6. *How do the total amounts of radiation recorded at the stations during a period of six months compare with each other?*

During the first half year under investigation the total amount of sun and sky radiation was largest at Bloemfontein, next in amount was that at Johannesburg and at Nelspoort Sanatorium. At the coast, Cape Town and Port Elizabeth had an approximately equal amount of radiation. Durban's amount was distinctly smaller. Durban, being the station with the smallest amount of radiation during the first half year, recorded 22 per cent. less than Bloemfontein which had the greatest amount.

The second half year showed a greater amount of radiation at Johannesburg than at the coastal stations. These recorded fairly similar amounts during the period.

The total for the year was distinctly larger at Johannesburg than at the three coastal stations.

7. *How does the amount of radiation obtained in South Africa compare with the amount in Nairobi (Kenya), Davos (Switzerland) and Bad Nauheim (Germany)?*

In winter the amount of sun and sky radiation at Johannesburg was distinctly larger than at Davos situated at a similar altitude above sea-level and it was 5 to 10 times larger than at Bad Nauheim at a low altitude.

During two months in midsummer the amount at Davos was slightly larger than at Johannesburg during the comparable period.

Nairobi experienced a greater amount of radiation during the six months under investigation than any of the other places concerned in this comparison.

The ratio between the highest summer and lowest winter readings per month was 2·0 : 1 at Johannesburg, 4·5 : 1 at Davos and 10·4 : 1 at Bad Nauheim.

The yearly total amount at Johannesburg was 122 per cent. of what was received in Davos; Bad Nauheim obtained only 69 per cent. of that amount.

B. COOLING TEMPERATURE.

1. During winter the mean values of the cooling temperature showed the greatest extremes at the inland stations, particularly at Johannesburg. Bloemfontein recorded higher readings at night, and Nelspoort distinctly lower readings during day-time than Johannesburg. The average conditions at the three coastal stations showed no very distinct differences. Throughout the year Durban's mean cooling temperature values were the highest. Next in order was Port Elizabeth, followed by Cape Town.

2. The rapid decrease of cooling temperature in the afternoon continued after sunset at the inland stations but not at the coastal stations. In the latter the rapid decrease only lasted until sunset, immediately after which the drop became much more gradual.

3. The average increase of the mean cooling temperature from winter to summer was great at the inland stations, but small at the coastal stations.

4. In winter the monthly average cooling temperature was distinctly lower at the inland than at the coastal stations, in summer this difference was not pronounced.

5. The mean *maximal cooling* temperatures showed no regular difference between the interior and the coast, whereas the mean *minimal* readings were distinctly lower at the inland stations.

SOUTH AFRICAN SOLAR RADIATION SURVEY.

6. The absolute highest cooling temperature of 52.0° was registered at Port Elizabeth in August and in January, the absolute lowest reading of 4.0° was recorded at Johannesburg in September, 1937.

REFERENCES.

- BÜTTNER, K. (1938). *Physikalische Bioklimatologie*. Akademische Verlagsgesellschaft, Leipzig.
- DE VILLIERS, G. D. B. (1939). A climatic study with special reference to delayed foliation of deciduous fruit trees. *D. Sc. Thesis*, Stellenbosch University.
- ISRAEL KÖHLER, H. (1937). *Das Klima von Bad Nauheim*. Verlag Theodor Steinkopff, Dresden u. Leipzig.
- LINDHOLM, F. (1929). Normalwerte der Gesamtstrahlung und der auf die Cadmiumzelle wirksamen Ultraviolettstrahlung der Sonne für Davos. *Festschrift für die 110. Jahresversammlung der Schweizerischen Naturforschenden Gesellschaft in Davos*. Verlag Benno Schwabe & Co., Basel.
- MATHESON, M. (1939). An ecological study of light and temperature relations in typical "purple Veld" of the highveld. *S. Afr. J. Sci.*, Vol. 36, p. 257.
- PFLEIDERER, H. (1936). Die Dosierung Klimatischer Heilmittel. 3. Internationaler Kongress für Lichtforschung Wiesbaden.
- RIEMERSCHMID, G. (1936). Preliminary results of measurements of the solar radiation at Durban and Nelspruit Sanatorium. *S. Afr. Med. J.*
- RIEMERSCHMID, G. (1937). Messungen der Strahlung und der Abkühlung als Dosierungsgrundlage in der Heliotherapie. *Strahlentherapie*, Vol. 59, pp. 690-710.
- RICHARDS, S. J. (1939). A survey of the ultraviolet solar radiation at Johannesburg. *S. Afr. J. Sci.*, Vol. 36, pp. 132-149.

Inlu

	hr.	16-17 hr.	17-18 hr.	18-19 hr.	19-20 hr.	20-21 hr.	21-22 hr.	22-23 hr.	23-24 hr.
1937—									
July		26.3	20.4	16.6	13.8	12.3	11.5	10.4	9.9
Aug		30.1	24.6	21.2	18.2	16.5	15.6	14.9	14.2
Sept		30.0	26.3	23.3	20.7	19.3	18.4	17.7	17.0
Oct		35.2	32.3	28.0	25.9	24.5	23.4	22.7	22.4
Nov		38.1	35.6	30.9	29.3	27.9	27.3	26.3	25.9
Dec		32.2	29.9	26.8	25.6	24.9	24.6	24.2	24.1
1938—									
Jan		35.5	32.5	29.1	27.9	26.8	26.4	26.1	25.7
Febr		33.7	31.4	27.7	26.5	25.3	24.2	23.3	22.7
Mar		35.5	33.4	30.2	27.9	26.6	25.8	25.2	24.7
Apr		31.3	27.1	24.0	22.5	21.6	21.3	20.7	19.9
May		30.1	24.7	20.8	18.7	17.7	17.2	16.3	15.9
June		—	—	—	—	—	—	—	—

1937—									
July		24.0	18.4	16.2	15.6	15.7	15.2	15.3	14.4
Aug		30.9	26.4	23.0	22.1	21.6	20.8	20.3	19.5
Sept		32.9	29.2	25.3	24.0	23.1	22.3	21.0	20.8
Oct		36.5	33.6	29.8	28.3	27.3	26.1	24.8	24.1
Nov		38.6	36.3	33.1	30.4	29.5	28.7	27.5	26.6
Dec		37.1	35.6	32.6	29.4	28.2	27.4	26.6	25.9
1938—									
Jan		38.4	36.0	32.7	29.7	28.5	27.9	27.0	26.5
Febr		35.8	32.5	29.8	28.3	27.9	27.2	26.4	25.7
Mar		38.2	35.7	31.6	29.6	28.8	28.2	27.6	26.9
Apr		—	—	—	—	—	—	—	—
May		—	—	—	—	—	—	—	—
June		26.0	22.1	20.8	19.8	18.9	17.7	16.8	16.3

1937—									
July		21.8	18.6	17.0	15.8	14.7	14.0	13.3	12.7
Aug		28.0	23.5	22.0	20.9	19.9	18.9	18.0	17.0
Sept		30.0	25.5	23.3	22.3	21.4	20.2	19.3	17.8
Oct		32.9	30.4	27.1	25.6	24.6	23.8	22.3	20.3
Nov		36.6	34.1	30.2	28.3	27.4	26.2	24.9	23.6
Dec		33.9	32.1	28.2	25.3	24.6	24.3	22.8	21.6
1938—									
Jan		—	—	—	—	—	—	—	—
Febr		—	—	—	—	—	—	—	—
Mar		37.7	34.4	31.5	30.1	29.4	28.5	27.6	26.5
Apr		31.2	28.1	25.7	25.0	24.5	23.8	23.1	22.2
May		—	—	—	—	—	—	—	—
June		22.3	20.1	18.9	18.5	16.8	16.3	16.0	15.4

Months.

14-15 hr.	15-16 hr.	16-17 hr.	17-18 hr.	18-19 hr.	19-20 hr.	20-21 hr.	21-22 hr.	22-23 hr.	23-24 hr.
32.3	31.0	28.6	25.9	25.7	25.5	24.6	24.2	24.1	23.9
33.8	31.9	30.2	27.7	27.2	27.2	26.8	26.5	26.1	25.8
35.1	33.6	31.5	29.3	28.0	27.6	27.3	26.7	26.5	26.5
34.8	33.3	32.1	29.7	27.9	27.6	27.4	27.0	27.0	26.7
36.0	34.5	32.6	30.5	29.1	28.5	28.5	28.4	28.3	28.0
37.1	36.1	34.2	32.8	31.0	30.2	30.1	30.0	29.4	29.3
36.6	35.5	33.5	32.0	30.3	29.5	28.9	28.7	28.3	28.0
39.3	38.0	35.7	33.4	31.7	31.2	31.0	30.8	30.4	30.4
39.7	37.8	36.0	33.6	31.9	31.7	31.5	31.2	30.9	30.7
37.1	36.0	34.3	31.9	30.9	30.9	30.4	30.0	29.9	30.0
35.0	33.7	31.6	29.5	28.7	28.5	28.2	27.8	27.7	27.2
33.0	32.5	30.2	27.6	26.8	26.1	25.6	25.1	24.8	25.0

31.7	30.5	27.2	23.8	22.8	22.6	22.3	22.0	21.8	21.8
34.1	32.1	29.2	25.7	25.2	24.9	24.8	24.2	24.0	23.8
30.9	29.8	27.5	24.1	22.6	22.5	22.4	22.4	22.4	22.3
32.3	30.9	29.2	26.5	24.4	24.1	24.1	23.5	23.4	23.4
34.7	33.3	32.3	30.5	27.8	26.9	26.5	26.4	25.9	25.8
35.7	35.1	33.3	31.4	29.2	27.9	27.7	27.7	27.6	27.5
37.5	35.8	34.2	32.3	29.5	28.7	28.6	28.5	28.1	28.1
37.2	36.0	34.5	32.3	30.8	28.9	28.6	28.7	28.9	28.4
37.5	36.2	33.6	31.1	29.5	29.3	29.9	29.8	29.9	29.7
33.1	31.6	29.6	26.9	26.4	26.2	25.9	25.9	25.7	25.7
30.7	29.1	26.7	24.0	22.7	22.7	22.6	22.6	22.3	22.2
31.0	28.7	25.4	23.0	22.6	22.2	21.8	21.7	21.4	21.2

28.7	27.1	24.2	22.3	21.1	21.1	20.9	20.5	20.2	19.8
32.4	31.2	28.4	23.7	22.5	22.3	22.0	22.0	21.7	21.7
31.1	29.4	27.0	24.4	21.9	21.6	21.4	21.1	21.0	21.0
34.8	33.3	30.8	26.9	23.1	22.3	22.3	22.2	22.1	21.0
36.0	34.8	32.5	29.4	25.8	24.3	23.9	23.7	23.6	23.6
36.6	35.5	33.5	31.2	27.5	25.4	25.1	25.0	25.0	25.0
35.7	34.6	32.9	31.0	27.5	25.6	25.0	24.8	24.0	24.8
36.3	35.0	33.3	30.7	26.5	25.5	25.3	25.1	24.9	25.0
37.0	35.2	32.9	29.5	26.1	25.8	25.6	25.8	25.4	25.5
32.5	31.6	29.3	25.5	24.6	24.2	23.7	24.0	23.9	23.9
30.7	29.0	26.7	24.0	23.4	23.0	22.7	22.5	22.4	22.3
31.8	29.8	26.0	23.4	22.7	22.3	22.0	22.0	21.6	21.4

4-5 hr.	5-6 hr.	6-7 hr.	7-8 hr.	8-9 hr.	9-10 hr.	10-11 hr.	11-12 hr
28.2	22.5	18.9	16.0	14.4	13.5	12.6	12.0
34.4	31.4	27.4	25.3	23.9	23.0	22.2	21.8
33.8	31.3	27.9	26.7	25.7	25.1	24.5	24.2
32.3	28.4	25.0	23.0	22.0	21.4	20.7	20.2

27.4	22.4	19.6	18.9	18.7	18.0	17.8	16.9
36.0	33.0	29.4	27.6	26.6	25.7	24.4	23.8
37.1	34.7	31.7	29.1	28.2	27.8	26.7	26.0

25.3	21.4	19.8	18.6	17.5	16.8	15.9	15.2
33.2	30.0	26.9	25.4	24.5	23.4	22.2	20.6

1918 Seasons.

2-3 hr.	3-4 hr.	4-5 hr.	5-6 hr.	6-7 hr.	7-8 hr.	8-9 hr.	9-10 hr.	10-11 hr.	11-12 hr.
33.0	31.4	29.4	26.8	26.4	26.3	25.7	25.3	25.1	24.8
35.3	33.8	32.1	29.8	28.3	27.9	27.7	27.4	27.3	27.1
37.7	36.5	34.5	32.7	31.0	30.3	30.0	29.8	29.4	29.2
37.3	35.8	34.0	31.7	30.5	30.4	30.0	29.7	29.5	29.3

32.0	32.3	28.2	24.7	24.0	23.7	23.5	23.1	22.9	22.8
32.0	31.0	29.7	27.0	24.9	24.7	24.3	24.1	23.9	23.6
36.8	35.6	34.0	32.0	29.8	28.5	28.3	28.3	28.2	28.0
33.8	32.3	30.0	27.3	26.2	26.1	26.1	26.1	26.0	25.9

30.5	29.1	26.3	23.0	21.8	21.7	21.4	21.2	20.9	20.7
34.0	32.5	30.1	26.9	23.6	22.7	22.5	22.3	22.2	22.2
36.2	35.0	33.3	31.2	27.2	25.5	25.1	25.0	24.9	24.9
33.4	31.9	29.6	26.3	24.7	24.3	23.7	24.1	23.9	23.9

1938.

	February.	March.	April.	May.	June.
Johannesburg.....	42·4 20·8 19·0	36·3 22·9 19·5	34·3 17·3 19·0	34·3 13·9 21·3	— — —
Bloemfontein.....	41·6 22·5 16·9	31·0 22·9 18·7	— — —	— — —	31·0 13·5 17·5
Nelspoort Sanatorium....	42·4 — —	35·7 22·8 19·6	37·5 17·2 18·5	— — —	26·7 11·5 15·2
Durban.....	42·0 28·6 13·7	39·4 29·0 13·0	37·5 28·3 11·1	35·6 25·2 12·3	35·6 22·4 13·2
Port Elizabeth.....	39·2 26·9 11·9	35·5 27·9 11·3	32·4 24·2 11·1	32·7 20·8 11·6	32·7 18·8 13·9
Cape Town.....	35·1 23·9 14·7	34·1 23·9 11·2	32·3 22·5 11·6	34·1 20·6 11·7	34·1 19·7 14·4

Each Month.

1938.						
er.	January.	February.	March.	April.	May.	June.
12·5	46·9 17·1	42·3 16·3	46·0 19·4	45·5 12·0	41·0 8·0	
17·9	49·3 17·1	45·3 17·5	47·7 18·8			38·7 5·5
10·6			46·5 19·3	43·6 10·7		31·7 8·0
23·8	49·6 19·8	46·4 21·4	45·6 23·7	44·3 22·9	42·4 20·9	39·9 18·3
20·6	52·0 18·8	46·9 20·0	45·8 21·3	45·4 18·3	39·8 14·9	40·9 13·9
21·2	48·5 19·4	45·6 21·2	47·7 19·1	43·4 18·7	42·0 17·3	46·2 14·1

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